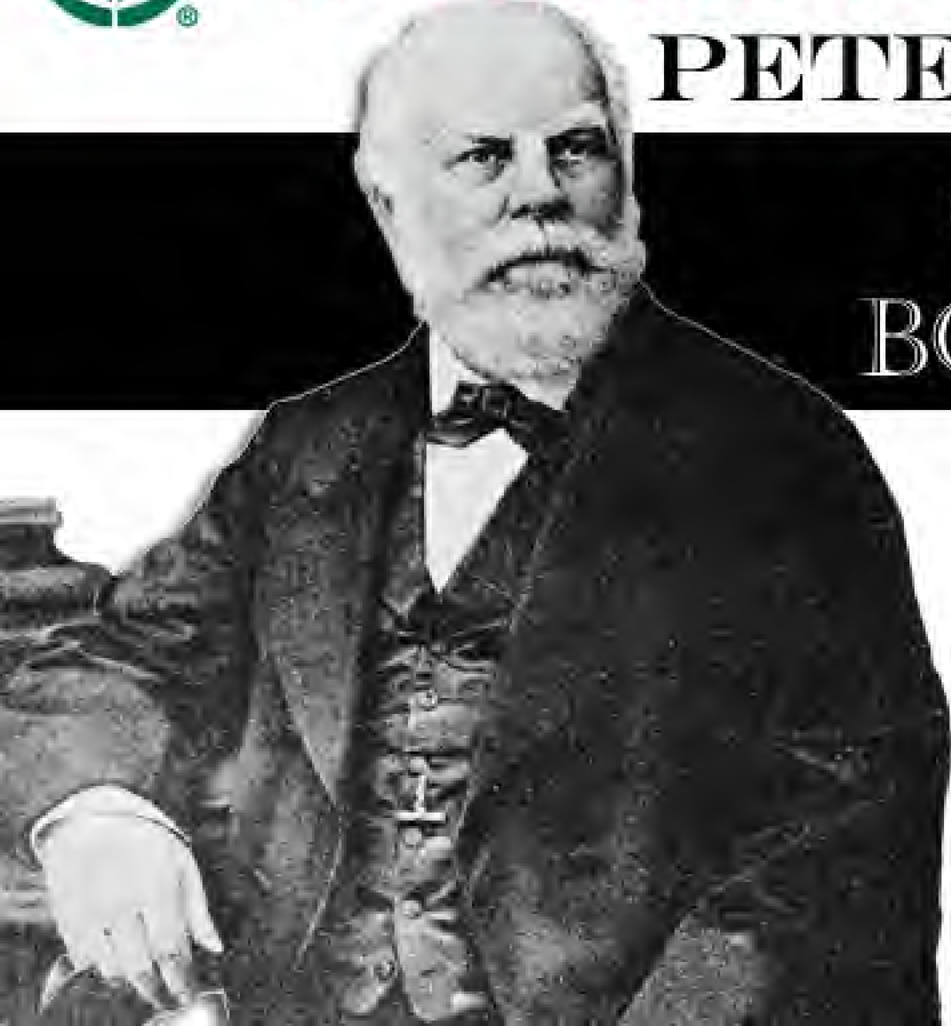
MISSOURI BOTANICAL GARDEN
PETER H. RAVEN LIBRARY



GEORGE ENGELMANN BOTANICAL NOTEBOOKS

Pagination Note:
Since many of the items lack a specific page number, the page number displayed online refers to the sequentially created number each item was given upon cataloging the materials.

Engelm

THE GENUS ISOËTES IN NORTH AMERICA.

By DR. GEORGE ENGELMANN.

From the Transactions of the St. Louis Academy of Science, Vol. IV., No. 2.

Read February, 1882.

0 1 2 3 4 5 6 7 8 9 10
cm
copyright reserved
MISSOURI
BOTANICAL
GARDEN

0 1 2 3 4 5 6 7 8 9 10
cm
copyright reserved
Missouri
Botanical
Garden

14858

The Genus ISOËTES *in North America.*

By Dr. GEORGE ENGELMANN.

§ 1. *History of* ISOËTES *in North America.*

The *Isoëtes*, insignificant and apparently sterile as they are, were long overlooked or ignored by our botanists, so that until thirty or forty years ago very few specimens were collected, and none were distinguished from *I. lacustris*, if we except Nuttall's guess at his Oregon discovery; but the genus has attracted so much attention, and lately so many forms have become known, that it seems to me an interesting task to trace up the history of the discovery of the different species and their varieties, and of the area of their distribution, and then the date of their publication, before I enter into their scientific description.

I. DISCOVERY.

1806 (?). The first notice which we have of an *Isoêtes* in North America is given in Pursh's Flora, ii. 671, where he states that "*Isoêtes lacustris*" grows in the bottom of Oswego river, near the falls, and adds his *v. v.*, which means that he saw it living, and therefore probably found it himself; and as he travelled through the regions near the Great Lakes in 1806, it was probably in that year that he met with it. I have not seen Pursh's specimens, but doubt not but that it will have to be referred to *I. echinospora*, var. *Braunii*, the only form thus far known from Western New York.

1815. Th. Nuttall collected "*I. lacustris*," abundant along the inundated gravelly and miry shores of the Delaware at Gibsonville (now a part of Philadelphia) on Aug. 22d, according to the label of a specimen in Collins' Herbarium, presented to me by E. Durand. It proves to be *I. riparia.*

1820 (?). L. von Schweinitz obtained in the Catskill Mountains in New York *I. lacustris;* some of his specimens are now found in the Herb. Philad. Acad. Natural Science and one in the St. Petersburg Imperial Herb. Some of them are labeled "Catskill Mountains" and others "Bethlehem," the latter, which was von Schweinitz's residence, probably by mistake. One of the specimens was loaned by the late Elias Durand—in whose possession it was—to Durieu de Maissonneuve, who founded on

MISSOURI BOTANICAL GARDEN
GEORGE ENGELMANN PAPERS

it his I. MACROSPORA. No date being indicated on the labels, the above-mentioned year is a mere guess.

1825 (?). Jens Vahl collected in Greenland a small *Isoëtes*, referred to *I. lacustris*, which proves to be one of the forms of *I. echinospora*.

1831. J. W. Robbins gathered an *Isoëtes* near Uxbridge, Mass., which I recognize as *I. riparia*.

1832. C. J. Moser, who collected for the German *Unio itineraria*, obtained specimens on the Lehigh river near Bethlehem, Pa., and near Philadelphia, both of which were distributed to the subscribers as *I. lacustris*. One of these (in Herb. Bernhardi, now in the Herb. Missouri Bot. Garden) represents *I. Engelmanni*; another, which I have seen in Europe, is *I. riparia*.

1834. Th. Nuttall discovered an *Isoëtes* on the Columbia river in Oregon, which I saw in E. Durand's Herb. with Nuttall's own label, *I. opaca*; it was afterwards named I. NUTTALLII.

About the same year Drummond collected "*I. lacustris*" on the Saskatchawan, according to Hooker's Fl. Bor. Am. ii. 268, which I have not been able to compare and to identify.

1840. J. W. Robbins found *I. lacustris* near Uxbridge.

1842. Rugel discovered an *Isoëtes* in Lake Imonia in Florida, which was soon afterwards distributed in Europe by Shuttleworth under the name of I. FLACCIDA. None of his specimens are believed to exist in America.

In the same year N. Riehl and myself found near St. Louis, Missouri, the species which from my specimens was by A. Braun named I. ENGELMANNI.

1843. Chas. Geyer found in Western Idaho *I. Nuttallii*, according to A. Braun, who examined the specimens in the Kew Herbarium.

In the same year S. Tuckerman collected *I. lacustris* in the Echo lake in New Hampshire.

1844. Wm. Zantzinger rediscovered the *Isoëtes* on the banks of the Delaware near Philadelphia. His specimens, sent to me, are the type of my I. RIPARIA.

1845. T. W. Robbins found in Massachusetts *I. echinospora*, var. *Braunii*.

1848. E. Tuckermann discovered near Boston the species which was by A. Braun named for him I. TUCKERMANI.

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

1850. A. W. Chapman found in Northern Florida a peculiar *Isoëtes*, which proved to be a large-spore form of *I. flaccida*, and was named var. CHAPMANI.

1853. E. Hall discovered in his fields near Athens in Central Illinois the species which was afterwards named by J. Gay I. MELANOPODA.

1856. I found *I. echinospora*, var. *Braunii*, in Lake Winnipiseogee in New Hampshire, the type of I. BRAUNII, Durieu.

1857. E. D. Eaton obtained *I. Engelmanni* for the first time in the New England States.

1860. Wm. Boott found near Boston the form of *I. echinospora*, which was named from his specimens I. MURICATA by Prof. Durieu, the present *I. echinospora* var. *muricata*.

1862. Th. C. Porter discovered near Lancaster, Pa., the largest American *Isoëtes*, *I. Engelmanni*, var. VALIDA.

In the same year G. Vasey found *I. melanopoda* in Iowa.

1863. I. Macoun obtained *I. echinospora*, var. *Braunii*, in West Canada.

In the same year Wm. M. Canby discovered in Maryland I. SACCHARATA.

1865. Leidy and Porter collected *I. lacustris* near the outlet of Lake Superior.

In the same year *I. Tuckermani* was rediscovered near Boston by Wm. Boott.

1866. Chs. Wright discovered I. CUBANA in Eastern Cuba.

In the same year H. Bolander found two new species in the Sierra Nevada of California, I. BOLANDERI and I. PYGMÆA.

1867. Wm. Boott got near Boston the species named after him I. BOOTTII, now known as *I. echinospora*, var. *Boottii*.

1869. Wm. M. Canby discovered on the Stone Mountain in Georgia the curious little I. MELANOSPORA.

In the same year S. Watson found *I. echinospora*, var. *Braunii*, in Utah.

1871. E. Hall gathered beautiful specimens of *I. Nuttallii* on the Columbia river.

1872. The same traced *I. melanopoda* to Texas.

1873. T. P. James got *I. echinospora*, var. *Braunii*, in Nova Scotia and C. C. Parry found *I. Bolanderi* in Yellowstone lake in Wyoming.

1875. G. D. Butler discovered in the Indian Territory the species named for him I. BUTLERI, and with it a new locality for *I. melanopoda.*

1878. C. G. Pringle found in Lake Champlain the form of *I. echinospora*, which I have designated as var. ROBUSTA.

1879. M. E. Jones met with *I. Bolanderi* in Utah.

1880. A. Gattinger discovered near Nashville, Tennessee, a *I. Butleri*, var. IMMACULATA.

1881. I collected *I. lacustris* var. PAUPERCULA in Grand Lake, Middle Park, Colorado, and C. G. Pringle found the same in Northern California.

2. PUBLICATION.

1753. Linnæus published in his *Species Plantarum*, ed. i., his *Isoëtes lacustris*, the only species known to him.

Neither Michaux nor any of the older writers on American plants knew of any North American *Isoëtes.*

1816. Pursh, Fl. Am. Sept. ii. 671, mentions "*I. lacustris*" from Oswego river, Western New York, which is most probably *I. echinospora*, var. *Braunii*, the only species thus far known from that region.

1818. Nuttall, Gen. ii. 253, has "*I. lacustris*" from the miry shores of the Delaware near Philadelphia, which cannot be any other than *I. riparia ;* he also gives Pursh's habitat.

In the same year Barton, Fl. Philad. ii. 213, has "*I. lacustris*" from Philadelphia, which may include both *I. riparia* and *I. Engelmanni.*

1824. Elliott knows no *Isoëtes.*

1826. Torrey (Comp. Fl. North. & Middle States) gives as habitat of "615, *I. lacustris*," bottoms of lakes, evidently without having himself seen it.

In the Flora Cestrica of the same year Darlington does not mention the genus.

1827. Sprengel, Syst. Plant. iv. 9, knows only *I. lacustris* with three varieties.

1833. Beck in his Botany repeats Pursh's and Nuttall's localities.

1840. Hooker, Fl. Bor. Am. ii. 268, mentions "*I. lacustris*" from the Saskatchawan. This may be the true *lacustris* or a form of *echinospora*, either of which may be expected in those regions.

1843. Torrey, Flora of New York, ii. 514, "*I. lacustris*," a mere repetition of Pursh's statement.

1844 Bory investigates the Genus, which until then had been very much neglected, and adds to the three then known species (*I. lacustris*, *Coromandelina*, and *setacea*) three new ones discovered in Algeria by Durieu de Maissonneuve.

1846. A. Braun, in Regensburg bot. Zeitung, No. 12, briefly characterizes *I. riparia*, Engelm., from Philadelphia; *I. Engelmanni*, A. Br., from Missouri, and *I. flaccida*, Shuttlew., from Florida.

1847. The Amer. Journ. Arts & Sciences, n. ser. iii. 52, publishes a translation of the above notice.

1848. A. Gray, in the first edition of the Manual Bot. North. States, p. 640, distinguishes the then known three northern species, *I. lacustris*, *I. riparia*, and *I. Engelmanni*.

1853. Darlington, Fl. Cest. ed. ii. p. 402, mentions "*I. lacustris*" as growing in shallow ponds in his district. This must refer to *I. Engelmanni*, the only species growing there in such localities.

1856. A. Gray, Manual, ed. ii., gives an almost verbal reprint of the first edition.

1860. Chapman, Fl. South. States, p. 602, describes *I. flaccida* as growing in "lakes and clear streams" in Middle and West Florida.

In the same year E. Tatnall, Cat. Pl. Newcastle Co., Delaware, enumerates *I. riparia* and *I. Engelmanni*, both of which names here probably stand for the latter.

1861. Durieu de Maisonneuve, Prof. of Botany at Bordeaux, in Bull. Soc. Bot. France, viii. p. 164, distinguishes and characterizes the two North European species *I. lacustris* and *I. echinospora*, heretofore thrown together.

1864. The same author, l. c. 101, 102, indicates four American *Isoëtes*: *muricata* from Massachusetts, *Braunii* from New Hampshire, *macrospora* from the Catskill Mountains, and *melanopoda* Gay (or Gay and Durieu) from Illinois.

In the same year A. Braun published a most important treatise on the Genus in his account of the *Isoëtes* of the Island of Sardinia, in which our species are frequently referred to.

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

1867. In the fifth edition of Gray's Manual, p. 676, I for the first time published *I. echinospora* as an American species, differing in several varieties from the European type—var. *Braunii* (*I. Braunii*, Dur.), var. *muricata* (*I. muricata*, Dur.), and var. *Bootti* (*I. Boottii*, A. Braun in lit.), all of them from the North-eastern States; also *I. Tuckermanni*, A. Braun in lit., from Massachusetts, and *I. saccharata*, Engelm., from Maryland.

1874. In Dr. Parry's Botanical Observations in Western Wyoming, Am. Naturalist, viii. 214, 215, I gave an account of the three western species: *I. Bolanderi*, Engelm.; *I. pygmæa*, Engelm., and *I. Nuttallii*, A. Br. in lit.

1877. My notice of *I. melanospora*, Engelm., from Georgia was published in the Trans. Acad. Sci. St. Louis, iii. 395, note.

1878. In Coulter's Botan. Gazette for January, p. 1, I gave an account of *I. Butleri*, Engelm., found in the Indian Territory west of Arkansas.

§ 2. *Morphology of Isoëtes.*

The species of *Isoëtes* are the simplest vascular plants known. They consist of a short trunk* with root-fibres at its base and leaves on its top, normally withoul branching and without any axillary productions.†

The TRUNK is generally depressed, broader than high, or flatter in some species (*I. Engelmanni*), and thicker and more globose in others (*I. melanopoda*), but its form is not constant; it is concave on the upper side and even somewhat funnel-shaped where the leaves are inserted, while the underside shows in almost all the N. American species two grooves and in many exotic ones three grooves, dividing the trunk more or less deeply into two or into three lobes. The number of lobes rarely varies, so that among the many hundreds and even thousands of American specimens which have passed through my hands, I have found only a single, normally bilobed, one with three lobes; this was an *I. riparia* from Philadelphia. In the 3-lobed species

---

* A very complete account of the structure of the trunk is given by H. Mohl in Linnæa xiv. (1840) 181, and of the whole plant and its morphology by A. Braun in the *Isoëtes* der Insel Sardinien. Monatsber. d. Berliner Acad. Wissensch. 1864.

† Abnormally the *Isoëtes* trunk has been seen divided, probably in consequence of some injury; I myself have seen a specimen of *I. Tuckermani* with four distinct bunches of leaves from a single trunk. K. Goebel found a proliferous *Isoëtes* with lateral shoots in place of spore cases. Bot. Zeitung, 1879, No. 1.

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

the transverse section is rather circular, but in the 2-lobed ones it is usually oblong or often somewhat rectangular, narrower in the direction of the grooves and wider in the opposite direction; the vertical section of the trunk shows a thickness of from 1 to 6 lines, and the transverse diameter a width of a few lines to more than one inch. In the centre of the trunk we find a small ligneous body, fibres from which enter the leaves and the roots. The mass of the trunk is a white parenchymatous or rather cortical tissue, the cells of which are filled with starch. The growth proceeds from the central ligneous body outwardly in two or three directions, corresponding to the two or three lobes, so that these lobes would spread laterally if their enlargement were not limited by the decay of the older (the preceding year's?) parts. We thus find that at the period of the most vigorous growth, about the beginning of fructification, the extreme lateral portion of the lobes becomes discolored, brownish, atrophied, and at last black, and is separated from the living tissues by a distinct line of demarcation, and at last generally falls off at the end of this or the beginning of the next season as a black mould-like mass. In some species, e g. *I. lacustris*, and in colder climates the atrophied cortical parts continue to cohere for several seasons, and in the Mediterranean *I. Hystrix* they do not seem ever to be detached, so that the trunk of this species reaches a larger size than any other.

The decaying portions are pushed obliquely upwards when the base of the trunk grows faster than the upper part (often in *I. Engelmanni*, and much more so in the Australian *I. tripus*), or horizontally outward (the ordinary case), or downward when the upper or leaf-bearing part expands more than the lower, root-bearing part. This last is the case in *I. Hystrix*, where the dead parts are turned downwards.

As the growth of the trunk takes place from the centre outward, the roots, originating from the youngest parts, start from the groove itself; and fresh and living, whitish, ones are only found in or near this groove: as they get older they are pushed to the sides, and finally die, becoming brown and black. The mass of roots found on *Isoëtes* specimens are mostly the entangled dead fibres, which, by the way, often conceal spores of the previous year, and therefore must be carefully examined when no fresh spores are attainable. The root-fibres, sometimes longer than the leaves, are always dichotomously, and often many times, branched. — The upper, concave, surface of the trunk bears the leaves, the innermost or youngest ones often yet immersed in the trunk.

The LEAVES are subulate or sometimes almost filiform tubular organs from a broad membranaceous sheathing base, mostly more or less quadrangular (broader and with sharper edges on the upper or ventral, narrower on the dorsal side), or in our terrestrial species more triangular and keeled on the back. Their sheathing bases form the *bulb*, which can be compared to the bulb of liliaceous plants; in fertile specimens it is always larger and thicker than the trunk, and in some of the larger ones, e.g. *I. Engelmanni* and *I. melanopoda*, attains a diameter of one or two inches. The leaves above this base contain four longitudinal air cavities, *lacunæ*, separated from one another by two dissepiments, a transverse and a median one, and irregularly divided by very thin transverse *septa*. The dissepiments are of different, pretty constant, thickness in the different species, thinnest in the amphibious and thickest in the terrestrial species, consisting in the former often of only 2 to 4, in the latter of 6 to 9 layers of parenchymatous cells; the median dissepiment is generally a little thicker than the transverse one. The anterior *lacunæ* are mostly somewhat larger than the posterior ones.

The epidermis of the leaf consists of rectangular cells, mostly much longer than they are wide; only in *I. pygmæa* are they comparatively short, and sometimes even square. In a few species the epidermis is entirely destitute of stomata, in the others it is pierced by stomata which communicate with the air-ducts, over which alone they are found. The presence or absence of stomata furnishes a very important character for the diagnosis and classification of the species. It was formerly thought that the submerged species had no stomata, and those species which bear their leaves more or less exposed to the air were provided with them; later discoveries, however, have shown that this rule does not always hold good, for we now know submerged species with stomata and emerged ones without them, and we have one submerged species (*I. echinospora*) in which the typical European form is destitute of stomata, while the American varieties show either a few stomata, often difficult to discover, or, rarely, numerous ones; so that in this interesting species the question arises whether the presence or absence of stomata *alone* can specifically separate forms otherwise scarcely distinguishable, as that acute observer of these plants, A. Braun, has maintained, or whether the stomata do *not* always play that important part in classification generally assigned to them. Below will be found directions for the investigation of the stomata.

The parenchyma of the leaf consists of a few or several layers of chlorophyll-bearing cells, 1. under the epidermis, 2. around the central bundle of vessels, and 3. forming the dissepiments, which cross each other in the centre of the leaf.

An important element in the leaf structure is found in the peripheral bast-bundles, which are present in some and absent in other species; and their presence often, but not always, coincides with the presence of stomata. When present they commonly form four bundles, two in the two anterior angles of the leaf, and two where the median dissepiments connect with the anterior and the posterior wall of the leaf; in *I. Nuttallii* I find only three bundles, the anterior median one being wanting; in *I. Cubana* six bundles are visible, the two additional ones being located where the transverse dissepiment unites with the outer wall. In some rigid-leaved land species, e.g. *I. melanopoda*, often several smaller accessory bundles are found scattered under the epidermis.

The examination of the fresh *Isoëtes* leaf is not very difficult; particles of the epidermis are easily removed and show the stomata, when present, very distinctly. Where there are few stomata, the epidermis from different parts of the leaf must be examined, and especially from the tip, as they are more apt to be found there. In dried specimens the leaf must be soaked, the *algæ* which often adhere to the surface have to be carefully scraped off, after which I make several sections ¼ or ½ line wide, lay them open by a vertical slit, detach the central bundle, and then scrape very gently the inner surface so as to remove the parenchymatous cells which obscure the appearance of the stomata This process can be aided by an immersion of the specimen in a weak solution of caustic potash. The work is often a difficult one when the specimen is very old or poorly preserved, and

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
Missouri Botanical Garden

requires a good deal of patience. Sometimes the application of iodine will very distinctly show the stomata by coloring their guard-cells blue when only these contain amylon, but of course not when the other cells are also filled with that substance. A magnifying power of 150 to 250 diameters is best adapted to well exhibit the stomata.

To find the bast-cells it is necessary to make the thinnest possible transverse sections of the leaf, boil them well, and, if they do not then show under water as bundles of minute, thick-walled, darkish cells close to the epidermis, very distinct from the much larger epidermis cells, the application of a solution of caustic potash, to clear the preparation, will readily bring them out. The same magnifying power which we use for the examination of the stomata may be applied for the study of the bast-bundles.

I would advise anyone who desires to study the structure of *Isoëtes* leaves to commence with well known species and good (if possible fresh) specimens, and make himself familiar with the manipulation and with the appearance of their parts under the microscope before he proceeds to study unknown and difficult specimens.

The arrangement of the leaves in the species with two-lobed trunks is at first distichous, and in *I. melanospora* it remains so through life; in all the others the leaves soon enter into a more complicated phyllotactic order; in the larger ones, with many leaves the $\frac{13}{21}$ and even the $\frac{21}{34}$ order is found.

The number of leaves varies from 5 or 10 (*I. pygmæa*, *I. melanospora*) to 100 or even 200 (*I. Engelmanni*, var. *valida*), and their length from ½ to 1 inch (in *I. pygmæa*) to 1–2 feet (in some forms of *I. flaccida* and *I. Engelmanni*); their color from light and fresh yellowish-green (*I. Engelmanni*) to dark and dull green *I. lacustris*); their rigidity is greatest in the terrestrial species, and also in some submerged ones; and least in most amphibious species, which often float their leaves on the surface of the receding water, or in some submerged ones, the leaves of which, taken out of the water, collapse like the soft hair of a wet pencil. The submerged species vegetate and retain their verdure throughout the winter (whence, it is said, the name of the genus is derived: *Isoëtes*, equal at all seasons), but the others lose their leaves soon after their maturity in autumn, some of our terrestrial ones even already in summer.

The broad membranaceous sheathing base of the leaf is without air cavities, stomata, or bast-bundles; in sterile leaves it gradually contracts into the leaf itself. Those leaves are usually sterile which develope at the beginning and the end of the season. The fertile leaves have in their base an excavation which bears the spore-case, *sporangium*, adnate with its back to the midrib. Above this excavation, and separated from it by a deep transverse depression or slit, we find a stipule-like organ of triangular more or less elongated shape, cordate at base, appressed to the leaf, which is termed the *ligula;* it is small, and in not very fresh leaves often mutilated and difficult to make out. The morphology of these parts is obscure and their diagnostic value not great.

The sporangium is oblong or circular (both forms often seen in the same species), from ½ to 1 line long in *I. melanopoda*; 1 to 2 lines in *I. pygmæa*, *Tuckermani*, *echinospora*, and *saccharata;* 1½ to 2½ lines in *I. lacustris*, *Bolanderi* and *flaccida;* often a little larger in *I. Butleri* and *Nuttallii;* 2 to 4 lines in *I. riparia*, *Engelmanni*, *melanopoda*, and *Cubana;* and in larger forms of *I. Engelmanni* I have seen it 8 to 9 lines long. It is somewhat flattened, and often slightly concave on the ventral side; it is entirely naked or (the usual case) it is on its sides and principally upwards partially covered by a fold of the ventral side of the leaf-base, the veil (*velum*); in a few species (*I. flaccida*, *melanopoda*, and *Nuttallii*) this fold extends over the whole sporangium, completely covering it (*velum completum*). The sac of the sporangium is composed of two layers of cells; the outer, epidermidal, layer consists of elongated, often variously bent or hooked and curiously interlaced cells, mostly thin-walled and transparent; in some species (e.g. *I. riparia*, *I. saccharata*, *I. melanopoda*) groups of brown, thick-walled, (so-called) sclerenchym-cells are mixed with the transparent ones, giving the spore-case a dotted appearance visible even to the naked eye. The spore-case is traversed by numerous parallel strings.

Some sporangia, called *macrosporangia*, contain larger or female spores (*macrospores* or *gynospores*), others are filled with the minute or male spores (*microspores* or *androspores*); these are called *microsporangia.* Almost all the species are monœcious, bearing macrosporangia on the base of the outer and microsporangia on that of the inner leaves. I am not aware that any exotic species behave differently, but here we have two species which deviate from this norm. *I. melanopoda* in Illinois as well as in the Indian Territory, from both of which localities I have examined several hundreds of specimens, is polygamous, i.e. monœcious as well as diœcious, and shows about an equal number of male, female, and monœcious plants. The allied *I. Butleri* is apparently always diœcious, no monœcious plants having been discovered among about one hundred examined. In *I. melanopoda* I have sometimes seen leaves with microsporangia irregularly interspersed among those that bear macrosporangia.

The macrospores are little spheroid bodies between one-fourth and three-fourths of a millimeter in diameter. Their surface is divided by a circular rim in a lower hemispherical and an upper three-sided pyramidal part, the three faces of which consist of spherical triangles and are separated from one another by three elevated ridges. The crusty surface of these spores, chalky-white or whitish in most species and dusky (when wet black) in *I. melanospora*, is rarely smooth, but generally sculptured and differently marked. The three upper triangles are sometimes marked differently from the lower hemisphere (especially in *I. Tuckermani*) or are smoother than that (often in *I. melanopoda*). To examine the spores well it is necessary to soak the leaf-base, carefully remove some of the wet spores and let them dry on the slide, for they must be examined dry, and best under a power of 50 or 60 diameters; but, to study the sculpture well, a power of 100 to 150 diameters is necessary. With the aid of this we find the macrospores—1. Minutely tuberculated or warty; the warts small and mostly somewhat depressed, distinct or sometimes somewhat confluent, in *I. pygmæa*, *Bolanderi*, *saccharata*, *melanospora*, *Butleri*, and *Nuttallii.*

2. With larger, broader tubercles, generally more distant and distinct, but also here and there confluent, worm-like; thus in *I. flaccida*, *melanopoda*, and *Cubana.*

3. With tubercles elongated into spines; these are simple and very fragile, or here and there confluent and forming sometimes short crests: *I. echinospora* and its forms.

4. With crests and ridges, distinct or anastomizing: *I. lacustris*, *Tuckermani*, and *riparia*.

5. The confluent crests form a regular net-work: *I. Engelmanni*.

The microspores are minute bodies of an ash-gray or a dusky color (dark gray in *I. pygmæa*, *Bolanderi* and *melanopoda*, deep brown in *I. melanospora*, *Butleri* and *Nuttallii*) and of a somewhat triangular-oblong shape, nearly straight on one and curved on the two other edges, more than half as wide as they are long, between 0.020 and 0.040 millimeters in the longest diameter. Their surface is smooth or minutely papillose or spinulose, the edges smooth or somewhat cristate. Their size furnishes good characters, but the condition of the surface much less so. They ought to be examined under water and with a power of about 400 diameters.

§ 3. *Biological Characters.*

After the maturity of the spores the leaves wither or rot away, the sporangia decay and set the spores free, which scatter near the base of the plant, often being retained between the matted roots.* The cellular mass of the macrospores developes into a *prothallus*, which bursts the spore-case through the opening of three valves which correspond to the three upper faces of the spore, and forms an archegonium, which is fertilized on coming in contact with the zoöspores emitted from the microspores, and thus gives rise to the young plantlet whenever moisture and temperature favor this process.

The germination of the late-maturing water-species probably takes place in the succeeding spring, at least in the more northern localities; in our land- and marsh-species it may be observed soon after their maturity in summer or in early autumn.

I have studied the whole process in *I. Engelmanni*, which I kept in cultivation for several years. At the end of July the spores were perfectly mature and the leaves were coming off. On the 28th of that month I spread out both kinds of spores on a muddy surface and kept them slightly covered with water, and fully exposed to the hot sunshine of that season. Three weeks later the first green points were seen and continued to come up until the end of October, while at that time the earlier ones had already developed 5 to 8 leaves, ½ to 1½ inches in length. The contents of the large or female spore-cell first developed into a dense cellular mass; this, enlarging, split the cell-coats as above described and protruded obliquely upwards a minute conical point, green inside, while on the lower edge of the opening, but still between the three valves (the lower hemisphere of the spore-case not being ruptured or perforated at all), a much smaller and rounded knob, the origin of the first rootlet, showed itself, bearing a large number of extremely fine capillary fibres; the bulk of the prothallus remained enclosed in the hemispherical part of the spore-case as a lateral knob, while the first leaf and then the first rootlet elongated; the spore-case was thrown off only when the former had acquired a length of 3 to 4 and the latter one of 2 to 3 lines, the capillary fibres still continuing at the origin of the rootlet. Soon afterwards a second leaf and a second rootlet were formed, both opposite to the laterally protruding spore-mass; after that new leaves and new roots spring up in distichous order between the older ones, the youngest in the centre. In twelve months the young plant, not yet fertile, shows the bilobed flat or rather concave trunk, 2 to 4 lines in diameter, with both ends strongly elevated, their edges already showing small masses of black decayed tissue (the remnants of the first year's growth). The leaves of these yearling plants, 10 to 15 in number, are 3 to 4 inches long, have abundant stomata, but as yet only a single very slender bast-bundle, median on the upper surface.

---

* It is therefore proper to examine among the roots for spores whenever none can be found on the plant; one or the other may be discovered there and help out the diagnosis which otherwise may rest in obscurity.

The species of *Isoëtes*, perhaps 40 to 60 in number (according to the views taken of the different forms, whether species or varieties), are distributed over the whole globe, apparently more abundant in the temperate than in the tropical zones. In North America we have 13 species, with 12 varieties, to which I add one from Cuba; from Mexico we have received as yet none. More are expected to be found when the attention of collectors is more earnestly directed to them.

Most of the species may be called water-plants, growing in stagnant or in slow-running water; a few are always submerged and are found out of water only in abnormal conditions, e.g. in unusually dry seasons. The majority are of amphibious growth, entirely or partially submerged dnring the wet seasons, in winter and especially in early spring; but at the growing season they partially get out of the water, leaving only their trunk and lower part of the leaves immersed. These species do not come to perfection when completely immersed, though they may not be entirely infertile; it seems that partial exposure to the atmosphere is necessary to their well-being. A variety of the amphibious species are the tidal ones, which are alternately emerged and submerged during the changes of the tides; they are found in the estuaries of some of our Atlantic rivers. Then we have a few species which we are justified in calling terrestrial, as we find them, when fully developed, on dry land; but it seems that for their germination and their growth in early spring they also require moisture and water; we therefore find them on low or flat grounds which may be overflowed in spring, or in springy localities, but they fully develope and become fertile only when out of water. *I. melanopoda*, which belongs to this class, normally matures in June or early in July, and its leaves wither before the end of that month; by keeping it immersed, however, I have kept it fresh and growing throughout the summer, but under these conditions it remained perfectly sterile. Those terrestrial species which grow on arid hills around the Mediterranean must require even less moisture, and are probably satisfied with temporary drenchings.

The submerged and the amphibious species are generally found, some in soft mud, others between gravel and stones; the amphibious ones generally in deep mud. Our terrestrial species grow mostly in heavy, retentive soil.

§ *4. Systematic Arrangement.*

Our 14 species can be classed—

1. According to the developement of the trunk; thus we have 13 species, all our North American ones, with a *bilobed*, and only the single Cuban one with a *trilobed trunk.*

2. According to their mode of growth:

a. Submerged species, which normally always grow under water: *I. lacustris*, *I. pygmæa*, *I. Tuckermani*, *I. echinospora*, and *I. Bolanderi.*

b. Amphibious species, which grow in water but have their leaves usually emerged: *I. saccharata*, *I. riparia*, *I. flaccida*, *I. Engelmanni*, *I. melanospora*, and probably *I. Cubana*.

c. *Terrestrial species*, which grow during the greater part of their life on dry (or moist) land: *I. melanopoda*, *I. Butleri*, and *I. Nuttallii*.

These divisions seemed to be the most natural ones so long as but few species were known, and when other characters, such as the presence or absence of stomata, seemed to correspond with and to confirm them; but, since we know more species and more about them, we have learned that structural and biological characters do not always go together; and, moreover, that some species are in some forms submerged and in others almost amphibious (*I. echinospora*), and that some amphibious ones become sometimes almost terrestrial (*I. Engelmanni*). A less important objection is, that the biological characters cannot be made out in herbarium specimens.

3. According to the condition of the velum:

a. A partial or narrow velum has *I. lacustris*, *I. pygmæa*, *I. Tuckermani*, *I. echinospora*, *I. saccharata*, *I. Bolanderi*, *I. riparia*, *I. Engelmanni*, *I. Howellii*, *I. melanopoda*, and *I. Cubana*. In *I. Butleri* the velum is almost completely absent.

b. A complete velum has *I. melanopoda*, *I. flaccida*, and *I. Nuttallii*.

The anatomical structure of the leaves, viz., the presence or absence of stomata and of peripheral bast-bundles, furnishes us valuable characters, and, though somewhat difficult to ascertain and therefore less practical, may after all have to be placed in the first line, as it seems to correspond best with the essential characters of the plant.

4. According to the presence or absence of stomata in the leaves:

a. Without any stomata are only *I. lacustris*, *I. pygmæa*, and *I. Tuckermani*. The typical European *I. echinospora* also belongs here, but the different American forms of this species must be classed among the next, though some of them have only very few stomata, often difficult to make out.

b. With stomata (generally abundant): *I. echinospora* (American varieties), *I. saccharata*, *I. Bolanderi*, *I. riparia*, *I. melanospora*, *I. Engelmanni*, *I. Howellii*, *I. flaccida*, *I. melanopoda*, *I. Butleri*, *I. Nuttallii*, and *I. Cubana*.

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

5. According to the presence or absence of peripheral bast-bundles:

a. Without bast-bundles: *I. lacustris*, *I. pygmæa*, *I. Tuckermani*, *I. echinospora*, *I. saccharata*, *I. Bolanderi*, *I. riparia*, and *I. melanospora*.

b. With bast-bundles: *I. Engelmanni*, *I. Howelli*, *I. flaccida*, *I. melanopoda*, *I. Butleri*, *I. Nuttallii*, and *I. Cubana*.

The comparative size or the sculpture of the spores, and the number and length of the leaves, furnish no legitimate grounds for classification; still it may be mentioned here, that the largest macrospores (0.45 to 0.80 mill. in diam.) are found in *I. lacustris*, *I. Butleri*, and *I. riparia;* the smallest (0.25 to 0.45 mill.) in *I. melanopoda*, *I. flaccida*, and *I. Engelmanni* var. *valida*.

The largest number of leaves, 50 to 200, are observed in the last mentioned form, in *I. melanopoda* and in *I. Nuttallii;* the smallest number, 5 to 20, in *I. pygmæa*, *I. melanospora*, *I. saccharata*, and *I. Bolanderi*.

The longest leaves (15 to 25 inches long) we meet with in *I. Engelmanni*, *I. flaccida*, and *I. Cubana;* the shortest (½ to 3 inches long) in *I. pygmæa*, *I. melanospora*, and *I. saccharata*.

The following classification of our species is proposed as the best I can find, though by no means a faultless one.

I. **Trunk bilobed.**

A. Submerged species with quadrangular leaves, without, or in 4 and 5 with few or many stomata and without peripheral bast-bundles; velum incomplete.

1. *I. lacustris*. 2. *I. pygmæa*. 3. *I. Tuckermani*. 4. *I. echinospora*. 5. *I. Bolanderi*.

B. Amphibious species with abundant stomata in the quadrangular leaves.

* Without peripheral bast-bundles (these are intermediate between the submerged and the truly amphibious species.)

† Velum partial.

6. *I. saccharata*. 7. *I. riparia*.

† † Velum complete.

8. *I. melanospora*.

* * With peripheral bast-bundles.

† Velum partial.

9. *I. Engelmanni*. 10. *I. Howelli*.

† † Velum complete.

11. *I. flaccida*.

C. Terrestrial species, maturing when entirely out of water, with abundant stomata and peripheral bast-bundles in the nearly triangular leaves.

* Velum partial or almost wanting.

12. *I. melanopoda*. 13. *I. Butleri*.

* * Velum complete.

14. *I. Nuttallii.*

II. **Trunk trilobed,** numerous stomata and bast-bundles in the quadrangular leaves; velum partial.

15. *I. Cubana.*

§ 5. *Geographical Distribution.*

Only a small part of the North American continent has been well explored for Isoëtes, and there, from Massachusetts to the Chesapeake Bay, they appear abundant enough; farther south, and in the whole interior and western part of the continent, they have thus far been found only in a few localities. Some species are quite local, as is the case also with many species of the old world, while others are widely distributed. Our two northern species are identical with, or closely allied to, European forms, all the others are quite distinct from such, so that there is scarcely more than a generic analogy between the species of our middle and southern regions with the Mediterranean ones or those of other regions of the globe.

The old Linnean *Isoëtes lacustris* is the only species which has been found to extend from the Atlantic to the Pacific States, and it probably occupies a northern belt of the northern hemisphere, though it seems not to have been discovered as yet in Asia. The American forms allied to *I. echinospora*, the other North European species, are the most common in the belt of northern States as far west as Michigan, and have been detected also on the western slope of the Rocky Mountains. Of the others, *I. Engelmanni* extends from Massachusetts to Georgia and westward to Missouri, though thus far not found anywhere else west of the Alleghany Mountains. *I. flaccida* is peculiar to Florida and *I. Bolanderi* to the lakes of the western mountain chains, the Rocky Mountains as well as the Sierra Nevada. *I. melanopoda* occupies parts of the Mississippi valley from Central Illinois to Northeastern Texas, while *I. Nuttallii* is the only species found in the valley of the Columbia river. All the other species seem to be nearly or quite local, *I. pygmæa*, in the Californian Sierra, but most of them on the Atlantic border; thus *I. Tuckermani* occurs only near Boston, *I. saccharata* on streams emptying into the Chesapeake Bay, and *I. melanospora* only on that peculiar and, botanically, so interesting rock, the Stone Mountain of Georgia. Some species which seemed local have lately assumed a little wider range, though yet quite restricted; among these I mention *I. riparia* of the banks of the lower Delaware river, which occurs also farther north, and *T. Butleri*, first known only from the Indian Territory, now also found in Tennessee. There can be no doubt but that some of the apparently local species will yet be found in a more extended area, when botanists will include in their researches these obscure and inconspicuous plants.

From the warmer parts of North America we know only *I. Cubana*, from Cuba; none have yet turned up from Mexico.

The following table will explain itself.

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

	Total species and varieties.	*I. lacustris.*	*paupercula.*	*I. pygmæa.*	*I. Tuckermani.*	*I. echin. Braunii.*	*robusta.*	*Boottii.*	*muricata.*	*I. Bolanderi.*	*I. saccharata.*	*I. riparia.*	*I. melanospora.*	*I. Engelmanni.*	*gracilis.*	*valida.*	*Georgiana.*	*I. Howellii.*	*I. flaccida.*	*I. melanopoda.*	*pallida.*	*I. Butleri.*	*immaculata.*	*I. Nuttallii.*	*I. Cubana.*
Greenland	1	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Nova Scotia	1	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Maine	2	....	....	....	....	1	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....
New Hampshire	2	1	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Vermont	4	....	....	....	....	1	1	....	....	....	....	1	....	....	1	....	....	....	....	....	....	....	....	....	....
Massachusetts	8	1	....	....	1	1	....	1	1	....	....	1	....	1	1	....	....	....	....	....	....	....	....	....	....
Rhode Island	2	....	....	....	....	....	....	....	....	....	....	....	....	1	1	....	....	....	....	....	....	....	....	....	....
Connecticut	1	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....
New York	3	1	....	....	....	1	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....
Ontario	2	....	....	....	....	1	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....
Michigan	2	1	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Pennsylvania	4	....	....	....	....	1	....	....	....	....	....	1	....	1	....	1	....	....	....	....	....	....	....	....	....
New Jersey	4	....	....	....	....	1	....	....	....	....	....	1	....	1	1	....	....	....	....	....	....	....	....	....	....
Delaware	3	....	....	....	....	....	....	....	....	....	....	1	....	1	....	1	....	....	....	....	....	....	....	....	....
Maryland	1	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Virginia	1	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....
Georgia	2	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	1	....	....	....	....	....	....	....	....
Florida	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....
Tennessee	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....
Illinois	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....
Iowa	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....
Missouri	1	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....
Indian Territory	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1	....	....	....
Texas	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....
Colorado	1	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Utah	2	....	....	....	....	1	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Wyoming	1	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Idaho	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....
Washington Territory	2	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....
Oregon	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1	....
California	3	....	1	1	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Cuba	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1

8 species and varieties have been found in Massachusetts.
4 " " " " Pennsylvania and New Jersey.
3 " " " " New York and California.
2 " " " " 10 States, Territories, or Provinces.
1 " " " " 15 " " " "

§ 6. *Enumeration of the Species.*

I. **Trunk bilobed.**

A. Submerged, normally growing under water, only in unusually dry seasons coming above the surface; leaves quadrangular, without peripheral bast-bundles; velum incomplete.

* Without stomata.

1. I. LACUSTRIS, Lin. Leaves stout, rather rigid, obtusely quadrangular, acute but scarcely tapering, dark or olive-green, 10 to 25 in number, 2 to 6 inches long; sporangium orbicular to broadly elliptical, not spotted, with a rather narrow velum; ligula triangular, short or somewhat elongated; macrospores 0.50 to 0.80 mm.* in diameter, marked all over with distinct or somewhat confluent crests; microspores smooth, 0.035 to 0.046 mm. in the longer diameter.— Syst. Veg. I. 1753; Durieu Bull. Bot. Soc. France, 8, p. 164, 1861; Gray Man. ed. 5, p. 675.

Var. PAUPERCULA with fewer (10 to 18), thinner, shorter (2 to 3 inches) leaves and smaller spores (macrospores 0.50 to 0.66 mm. diam.; microspores somewhat granulated, 0.026 to 0.036 mm. long).

A northern species of Europe and America, generally gregarious on gravelly soil in the bottom of lakes under 1 to 4 or 5 feet of water, farther south only on mountains; maturing in Sept. and Oct. Catskill Mountains, N. Y. *Schweinitz*, Echo Lake, Franconia Mountains, N. H. *Tuckermann*, *Engelmann;* in Massachusetts, in Fresh Pond near Cambridge, *W. Boott* and Uxbridge, *J. W. Robbins;* Brattleborough, Vt., *C. C. Frost;* Saulte de Ste. Marie on Lake Superior, *Porter and Leidy*. The variety in Grand Lake, Middle Park, Colorado, over 8,000 ft. alt., *Engelmann*, and in Castle Lake near Mt. Shasta, California, 7,000 ft. alt., *C. G. Pringle*. — This is the original Linnean species, formerly confounded with others, and first clearly established by Durieu, l. c. It is always readily recognized by its rigid, rather thick, not gradually tapering dark green leaves, which do not collapse when taken out of the water, and by the size and sculpture of the spores. The variety *paupercula* is based on western mountain specimens, and is characterized by the smaller proportions of all parts, and especially of the (for the species) unusually small microspores. Durieu, l. c. 11, p. 101, distinguished a form with exceptionally large macrospores (0.70 to 0.80 mm. diam.) as *I. macrospora* from a single specimen from the Herb. Acad. N. S. Philad., with the label "Catskill Mountains" in the handwriting of Schweinitz; but others show sometimes spores of similar dimensions, e.g. specimens from Lake Superior; and such have also been found in Europe, though there the spores rarely reach a size of over 0.65 to 0.70 mm.

2. I. PYGMÆA, Engelm. One of the smallest species with a few (5 to 10) short ($\frac{1}{2}$ to 1 inch long) stout, rigid, bright green leaves, abruptly

---

* I adopt for the smaller measurements the metrical system, which will gradually but surely supersede the old and clumsy method, while in the larger measurements, as the length of leaves, I still adhere to the foot and inch as the one yet best understood. The millimeter is, as is well known, equal to very nearly half a line.

tapering to a fine point, with very short, often almost square, epidermis cells; orbicular sporangium not spotted, with a narrow velum; macrospores 0.36 to 0.50 mm. thick, marked with minute, rather regular, distinct or rarely confluent warts; microspores 0.024 to 0.029 mm. long, almost smooth and brown.—Am. Naturalist, 8, 214.

Found only once, deeply immersed in a cold alpine stream on the eastern slope of the Mono Pass, California, 7,000 ft. alt., *H. Bolander*.—This curious diminutive species is a close ally to the last by the structure of the leaves and the mode of living, but is widely separated from it by the sculpture of the spores; the shortness of the epidermis cells is quite peculiar to it, and so are the close transverse partitions; the walls of the leaf and the dissepiments are thinner than in the last, consisting of only a few layers of cells. The minute tubercles of the macrospores are most distinct on the lower surface, but become sometimes confluent on the upper side.

3. I. Tuckermani, A. Braun in litt. A small plant with very slender tapering olive-green leaves (10 to 30 in number, mostly 2 to 3 inches long), the outer recurved, walls and partitions rather thick for the diameter of the leaf; sporangium mostly oblong, white or rarely brown-spotted, the upper third covered by the velum; macrospores 0.44 to 0.56 mm. diam., the upper segments marked with prominent, somewhat parallel and branching ridges, the lower half reticulated; microspores smooth or nearly so, 0.026 to 0.032 mm. long.—Engelm. in Gray Man. l. c. 676.

In several ponds and streams near Boston, maturing from August to October; first discovered by *E. Tuckermann*, 1848, in the Mystic river very near where it issues from the pond; in the same locality and in Mystic, Spy and Horn ponds, *W. Boott*, "always immersed in fresh water, sometimes only a few inches below the surface, often in places which are subject to a tide of almost two feet in height, generally gregarious and carpeting the bottom with an olive-green turf." The leaves are usually not longer than two or three inches, and, at least the outer ones, recurved; occasionally, in slender specimens, probably from deep water I have seen them straighter and over 5 inches long. The sculpture of the spores is very characteristic, wavy, somewhat branching ridges run from the three upper commissures in right angles; on the lower surface they interlace, covering it with an irregular network. Some specimens collected by Mr. Boott at the end of October seem to indicate a second growth, as within the circle of microspore-bearing leaves, and after the outer ones with their macrosporangia had fallen, an inner growth bearing macrosporangia was noticed. One of his specimens is of particular morphological interest, as it shows four heads or leaf-buds from the same healthy and vigorous trunk, three close together on top and a fourth on the side, separated from the others by a deep incision in the trunk. This division of the axis did not result from any proliferation of the leaves, but most probably from a lesion of the centre of vegetation, and is of very rare occurrence in this genus, where the simplicity of the axis is so particularly marked (see above p. 358).

4. I. ECHINOSPORA, Durieu. One of the smaller species with 10 to 30 or 40 soft bright green or sometimes reddish leaves, gradually and regularly tapering from a thick base to a very slender elongated point absolutely without stomata, 2 to 4 or sometimes 5 inches long; sporangia orbicular to broadly oval, unspotted, with a narrow velum; macrospores 0.40 to 0.50 mm. thick, densely covered with delicate, erect, truncate, or slightly forked spinules; microspores 0.030 to 0.034 mm. long, almost smooth.—Bull. Bot. Soc. Fr. 8, 164.

Only in Europe from Northern Italy to Germany, France and England, extending to Lapland and Iceland, but apparently not in America.

In this country we have a series of forms which have been distinguished by eminent anthority, especially on account of the presence of stomata so various in number and often so difficult to discover, and of a slight difference in the form and size of the microscopic spinules which cover the macrospores. I have thought best to unite them specifically with the European type, though it seems strange that in the European plant stomata should be absolutely absent, and it must remain subject to individual judgment, if not doubt, which view ought to be preferred. Nearest to the European true *I. echinospora* stands the var. *Braunii* and the other extreme is var. *muricata*, wide-ranging forms of a single type. The same difficulties, the same doubts, and the same solution, we find in studying some foreign forms and especially those allied to *I. velata* of the south of Europe.

* * Stomata few.

I. ECHINOSPORA, var. BRAUNII, Engelm. Rather small, with 13 to 15 green or reddish-green erect or spreading, rather short (3 to 6 inches long), tapering, soft leaves, generally with few stomata towards the tip only; sporangia orbicular to broadly elliptical, spotted, generally ½ or even ¾ covered by a broad velum; macrospores 0.40 to 0.50 mm. thick, rarely a little longer, covered with broad, retuse spinules, sometimes somewhat confluent, and then dentate or incised at tip; microspores 0.026 to 0.030 mm. long, smooth.—Gray Man. l. c. *I. Braunii*, Durieu l. c. 11, p. 101.

The most common species of our flora from New Jersey and Pennsylvania, northward and northwestward, sometimes on gravelly soil, at other places reported from soft mud, in ponds or slow-running streams, also near the banks of larger lakes or under the influence of tidewater, normally submerged from a few inches to several feet, in dry seasons sometimes getting out of water; associated with *Eriocaulon septangulare*, *Lobelia Dortmana*, *Sparganium*, *Scirpus*, *Eleocharis*, etc. New Jersey: in tidewater of Tom's river, a slender long-leaved form, *C. F. Parker*, *C. E. Smith*, and others; in a lake in Morris Co., *T. C. Porter*. Pennsylvania: Montrose, Susquehanna Co., *A. P. Garber;* Great Lake, Pocono Mountain, *Porter & Canby;* Presque Isle, Erie, *A. P. Garber*. New York: Catskill Mountains in the lake near the hotel, *G. W. Clinton;* Round Lake above Bolton, west of Lake George, on white sand, and in Lake Placide, *L. Lesquereux;* Luzerne Lake and in Niagara river below Buffalo, *G. W.*

Clinton; at the head of Goat Island, Niagara, between stones, *G. Engelmann*; Oneida Lake, *J. A. Paine*; in Oswego river, *F. Pursh*, probably (see p. 353). Massachusetts: Mystic Pond near its lower end, gregarious in soft mud in 1 foot of water, also in other parts of the same pond, and in Spot, Spy and Horn ponds, on sandy bottom, all near Boston, *W. Boott*; Hammond's Pond, *W. G. Farlow*; Concord brook, gregarious, on firm bottom, *H. Mann*; Beaver Pond near Beverly, *J. L. Russell*; Uxbridge, in Grafton Pond and several other ponds, *I. W. Robbins*. Vermont: Mt. Mansfield, in the Lake of the Clouds, *C. G. Pringle*, *H. Mann*, on gravelly bottoms, 1 to 2 feet deep; Lake Dunmore, *A. W. Chapman*. New Hampshire: Lake Winnipiseogee, in mud with *Gratiola aurea*, *Eriocaulon*, etc., *G. Engelmann* (these specimens were the types of Durieu's *I. Braunii*), *H. Mann*, *W. Boott*; Echo Lake in the Franconia Mountains (where Mr. Tuckerman and myself had found *I. lacustris*), *W. Boott*. Maine: Moose Lake on Kennebunk river, *C. E. Smith*. Nova Scotia, Shelburne, *T. P. James*. Greenland, in the south, "Tessermint," *I. Vahl* (perhaps this is the true *I. echinospora*; I could not well analyze the small and poor specimen in my possession). Westward the species has been found in Western Canada (Ontario) near Hastings and in a lake northeast of Belleville, on a muddy bottom, *J. Macoun*. Michigan: Bellisle in Detroit river, *H. Gillman*. Utah: Lake at the head of Bear river in the Uintah Mountains, at 9,500 feet alt., *S. Watson*; this is the most western and highest, quite isolated, locality known to me.

This form is most closely connected with the European type; the leaves are perhaps not quite so finely tapering; stomata can always be found, at least near the tip of the leaf; the sporangia, white in the type, are spotted with brown sclerenchym cells; the macrospores I cannot distinguish either in size or sculpture; the microspores I find a little smaller. I may state here that the name of *I. Braunii* is preoccupied, as it has already been given to one of the two species of the Tertiary deposits, the well marked spores of which have been discovered in the German Brown Coal strata; Prof. Braun therefore proposed for our plant, if it should eventually be considered distinct, the name of *I. ambigua*.

Var. ROBUSTA, Engelm., similar to the last, but much stouter, with 25 to 70 leaves, 5 to 8 inches long, with abundant stomata all over their surface; velum covering about one-half of the large, spotted sporangium; macrospores 0.36 to 0.55 mm. thick, with the sculpture of the last; microspores the same as in last.

In Lake Champlain, on the north end of Isle La Motte, on a firm sandy soil with silt, in 1 to 2 feet of water, *C. G. Pringle*. Larger and stouter than any form of the last, but principally distinguished from it by the abundance of stomata.

Var. BOOTTII, Engelm. l. c. Leaves erect, soft, bright green, fewer (12 to 20) short (4 to 5 inches long); stomata, mostly few, near the tip; sporangia nearly orbicular, pale-spotted, $\frac{2}{3}$ or more covered by the broad velum; macrospores 0.39 to 0.50 mm. thick, with longer and slenderer delicate, generally simple spinules; microspores 0.026 to 0.030 mm. long. —*I. Boottii*, A. Braun in litt.

Near Boston, in the Round Pond, Woburn, 2 to 3 feet under water, and in the brook of Tofit Swamp, Lexington, sometimes out of water, *Wm. Boott*. Very striking on account of the delicate green color of its soft leaves, and the long and slender spinules of the spores.

Var. MURICATA, Engelm. l. c. Leaves (15 to 20) long (6 to 12 inches), flaccid, bright green, with very few stomata; sporangium broadly oval, pale-spotted, about half covered by the velum; macrospores a little larger (0.40 to 0.58 mm. thick), with shorter and more confluent, therefore sometimes almost crest-like spinules: macrospores slightly rough on the edges, 0.028 to 0.032 mm. long.—*I. muricata*, Durieu l. c.

In the shallow and more rapid parts of Woburn creek, and in Abajona river, the main source of Mystic Pond, near Boston, scattered over a clean gravelly bottom and always submerged, *W. Boott*. Remarkable for its long flaccid leaves and the shorter spinules of the macrospores, which form sometimes crests so that Durieu could compare it with *I. riparia*.

5. I. BOLANDERI, Engelm. One of the smaller species with erect, soft, bright green leaves tapering to a fine point, 5 to 20 or 25 in number, 2 to 4½ inches long, with thin walls and partitions, and generally not many stomata; sporagium broadly oblong, mostly without any spots, with a narrow velum; ligula triangular; macrospores 0.30 to 0.40 or rarely 0.45 mm. thick, marked with minute low tubercles or warts, rarely confluent to wrinkles; microspores 0.026 to 0.031 mm. long, generally spinulose; rarely, in the Rocky Mountain form, smooth, deep brown.—Am. Naturalist, 8, 214.—*I. Californica* Engelm., name only in Gray Man. l. c.

A western mountain species, found gregarious in ponds and shallow lakes of the Sierra Nevada of California, northward to the Cascades and eastward to the Rocky Mountains: in little pools on meadows in the upper Tuolumne valley 9,000 to 10,000 feet alt., on Mt. Dana, on the Mono trail, in Mary's Lake near the summit, 7,000 feet alt., in small lakes about Cisco 4 500 to 5.000 feet alt, "mostly gregarious in mud covering gravel, in 1 or 2 feet of water," *H. Bolander;* Ice Lake, near Soda Spring station, 7,500 feet alt., with *Menyanthes trifoliata*, *Engelmann;* in many lakes of the high sierras, reported by A. Kellogg; on Mt. Adams, Washington Terr., *W. N. Suksdorf,* in the soft muddy bottom of a shallow pond near the falls of the Yellowstone river in Wyoming, nearly covering the muddy bottom, partly emerged near the banks, *C. C. Parry;* in a subalpine lake at Alta, Wasatch Mountains, Utah, *M E. Jones*, and in a lake in the Gunnison region, Western Colorado, covering ten acres of ground with *Menyanthes*, *T. S. Brandegee* —This species has much the appearance of *I. echinospora* var. *Bootti*, with its soft bright green leaves; the stomata are often difficult to make out.

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

B. Amphibious, partially emerged, submergedonly in the earlier period of their growth or temporarily; stomata always present.

* Without peripheral bast-bundles; intermediate between the submerged and the truly amphibious species.

† Velum partial.

6. I. SACCHARATA, Engelm. A small plant, usually with a flat, depressed trunk; leaves subulate, olive-green, spreading, 10 to 20 in number, 2 to 3 inches long; sporangium oblong, spotted, with a narrow velum; ligula triangular; macrospores 0.40 to 0.47 mm. thick, covered with very minute distinct or sometimes a little confluent warts; microspores papillose, 0.024 to 0.028 mm. long.—Gray Man. l. c.

On the banks of the Wicomico, below Salisbury, and of the Nanticoke rivers which empty into the Chesapeake Bay, eastern shore of Maryland, above salt water, scattered on a thin stratum of mud covering a bed of gravel, overflowed by the tides, in company with *Sagittaria pusilla*, *Eriocaulon*, *Tillaca simplex*, *Micranthemum Nuttallii*, etc., *W. M. Canby.* The trunk is in this species unusually flat, about half as thick as it is wide in the direction of the groove; about one inch of the base of the leaves is pale, and covered with mud agitated by the tides, the upper part is olive-green and when out of water apt to be borne down by mud; stomata abundant; macrospores as if sprinkled over with minute white grains of sugar, whence the name.

7. I. RIPARIA, Engelm. A larger plant with slender but rather rigid deep green leaves (about 15 to 30 in number), 4 to 8 inches long, rarely longer; stomata numerous, dissepiments thick, consisting of about 4 layers of cells; sporangia mostly oblong, distinctly spotted by groups of brown sclerenchym cells, ¼ or rarely ⅓ of it covered by the velum; macrospores among the largest, 0 45 to 0.65 mm. in diam., marked with jagged crests isolated, or anastomosizing, especially on the lower surface, which thus becomes somewhat reticulated; microspores more or less tuberculated, 0.028 to 0.032 mm. long.—Flora, Regensb. Mar. 31, 1846; Am. Jour. Arts & Sci. 3, p. 52, 1847: Gray Man. l. c.

On the banks of the lower Delaware river between the limits of the tides in mud covering gravel, from Burlington, *T. A. Conrad*, to Wilmington, *W. M. Canby*, and especially about Philadelphia, where *Nuttall* first discovered and *W. S. Zantzinger*, *E. Durand* and the later botanists have abundantly collected it, associated with *Elatine*, *Limosella*, *Micranthemum*, *Sagittaria pusilla*, etc.; also in millponds and still parts of streams in New England, Uxbridge, *J. W. Robbins*, Brattleborough, *C. C. Frost*, and northward, maturing in August and September. — Near *I. lacustris*, with leaves as dark green and almost as rigid, and with spores approaching it in size and sculpture, but readily distinguished by its stomata and by the spots on the sporangium; from *I. echinospora* var. *Braunii*, with which smaller forms it may possibly be confounded; it can always be known by the darker, stiffer leaves and especially by the character of the spores. Some of the Uxbridge specimens, entirely submerged 2 to 4 feet deep in water, have slenderer and longer (even 12 inches) leaves. The trunk, mostly thick, I have once found 3-lobed. Germinating spores and young plantlets were found in June by Mr. Durand indicating germination in spring and early summer.

Farther northward, in Maine, *J. W. Chickering*, and in Canada West, Crow river, Hastings Co., *J. Macoun* (here in running water with *Brasenia* and *Potamogeton*), a form occurs with very few stomata on leaves and apparently two weak bast-bundles, an upper and a lower one, very pale spots on the sporangia and smoothish microspores, which might be designated as var. *Canadensis*, but too little is known about it as yet to form a definite opinion.

† † Velum complete.

8. I. **MELANOSPORA**, Engelm. One of the smallest species, with a flat, only slightly bilobed trunk; leaves few (5 to 10, 2 to 2½ inches long), distichous, slender, tapering, light green, spreading; sporangium orbicular or almost obcordate, ½ to 1 line long, entirely covered by the velum, unspotted; ligula short-triangular, obtuse, or about semi-orbicular; macrospores 0.35 to 0.45 mm. in diameter, roughened with distinct or rarely somewhat confluent warts, dark colored; microspores 0.028 to 0.031 mm. long, smoothish or slightly papillose.—Transact. St. Louis Acad. Sci. 3, p. 395, note.

Stone Mountain near Atlanta, Georgia, covering the bottom of shallow excavations on the naked granite surface, a few inches deep and a few feet in diameter, holding about one inch of light, black soil and at best a couple of inches of water supplied only by rains and dews, and completely dried up and baked for weeks or months under the action of the glaring southern sun on the bare rock, when only the little shrivelled trunks with their black withered matted roots remain, to revive under a fresh supply of autumnal rains; with *Amphianthus pusillus*, discovered by *W. M. Canby*, observed since by *A. Gray* and myself; maturing in May and June. A cake of them taken home with me began to sprout soon after being moistened, and, vegetating in the room through winter, fully developed in early summer, and afforded a fine opportunity for studying this curious little species, interesting on account of its native locality, its endurance of drought, its mode of growth and the phyllotactic arrangement of its leaves, its entire velum and its dark spores; it seemed to thrive best when only the base of the leaves was covered with water. The trunk is unusually flat and only slightly grooved underneath and on one side, only about ½ to 1 line thick and 2 to 4 lines in the longer and not much more than half as much in the shorter diameter; distichous leaves soft and slender, their dissepiments consisting of only two layers of cells. The sporangia, ½ to ¾ line wide, readily separate from the leaf-bases, so that they are sometimes found adhering to the trunk after the leaf itself has already fallen away. The macrospores, only 8 to 20 in each sporangium, are black when moist and dark gray when dry; in some I find the warts much smaller than in others, but never wanting; microspores also quite dark brown.

* * With peripheral bast-bundles.

† Velum partial.

9. I. ENGELMANNI, A. Braun. Our largest species with numerous (25 to 100) long (9 to 20 inches or more) light green leaves with abundant stomata; sporangium usually oblong to linear-oblong, unspotted; velum narrow; ligula elongated from a triangular base; macrospores 0.40 to 0.52 mm. thick, delicately honeycomb-reticulated; microspores 0.024 to 0.028 mm. long, generally smooth.—Flora l. c.; Am. Jour. l. c.; Gray Man. l. c.

Var. GRACILIS, Engelm. Often submerged, with fewer (8 to 12) leaves, 9 to 12 inches long; the bast-bundles sometimes quite small, or only two of them.—Gray Man. l. c.

Var. VALIDA, Engelm. The stoutest of all our species; leaves 50 to 100 or even 200, 18 to 25 inches long, keeled on the upper side; sporangium often linear-oblong (4 to 9 lines long), ⅓ or often ½ or even ⅔ covered by the broad velum; macrospores rather smaller, 0.32 to 0.48 mm. thick; microspores 0.024 to 0.027 mm. long, spinulose,—Gray Man. l. c.

Var. GEORGIANA. Similar to the type; leaves few (in the only specimens seen 15, 10 to 12 inches long), rather slender; oval sporangium with narrow velum; macrospores larger, 0.48 to 0.56 mm. thick; microspores 0.028 to 0.031 mm. long, smooth.

In ponds and ditches, immersed in mud, rarely found in slow-running streams, in company with the ordinary vegetation of such localities, *Bidens*, *Polygonum*, *Lycopus*, *Carices*, *Leersia*, etc.; mature in summer; probably throughout the middle States, but thus far only found — from Massachusetts: Arlington brook, Alewife brook, West Cambridge brook, Woburn, *Wm. Boott*. Rhode Island: Newport, *W. G. Farlow*. Connecticut: Meriden, *F. W. Hall* — to New York: Peekskill, *W. H. Leggett*. New Jersey: *E. Durand*, *C. F. Austin*, and others. Pennsylvania, Bethlehem, *C. J. Moser*, *E. Durand*, *S. Wolle;* Delaware Water-Gap, *S. W. Knipe;* Darby, *J. G. Hunt;* Philadelphia, *E. Durand*, *C. E. Smith*, and others. Delaware: *Wm. M. Canby*, *A. Commons*. Virginia: Salt Pond Mountain, with *Parnassia asarifolia*, *W. M. Canby*. Missouri: St. Louis, *N. Riehl* and *G. Engelmann*, 1842, in a single locality, where it was soon afterwards destroyed by cultivation: not found otherwise west of the Alleghany Mountains. Var. *gracilis* seems to be a northern form: Brattleborough, in Clark's Pond, *C. C. Frost;* Colebrook's, in a shallow stream with gravelly bottom, *J. W. Robbins;* New Haven, in fresh water on a tidal shore, *D. C. Eaton;* Newport, *Bridges*, *G. Thurber;* Passaic river, near low-water mark, *J. Ennis*. Var. *valida* was discovered in Pennsylvania near Warrior's Mark, Huntington Co., and Smithville, Lancaster Co., *T. C. Porter;* and in Delaware, Wilmington, *W. M. Canby*. Var. *Georgiana* comes from a mountain stream, Georgia, the Horseleg creek,

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

a tributary of Coosa river, Floyd Co., in slow-flowing water about a foot deep, *A. W. Chapman.*

The trunk of this species is larger than I have seen it in any other, and more variable in form; sometimes it is quite flat and over one inch wide, especially in var. *valida*, or it is thick; and I have seen it even twice as high as it was wide, 4½ lines wide in the largest transverse diameter and 7 lines high; this, however, is a very unusual form. The plant is submerged in spring with the leaves partly floating; later, when the water recedes, the older leaves are spread out on the mud, but the later growth becomes erect; var. *gracilis* is often more or less submerged, and its weakly develepement is probably owing to this circumstance, while var. *valida* is the stoutest form we have, and one of the stoutest in the whole genus, perhaps only *I. Malinveriana* of the rice fields of Lombardy surpassing it. A very small form, only 5 inches high, has been collected in a springy place on a rocky hillside near Wilmington, Del., by A. Commons, otherwise not distinct. The Georgia variety, characterized by its larger spores, ought to be further studied. In my Missouri specimens I find, among many of the ordinary type with white sporangium, a few where this organ is uniformly brown, not spotted. The dissepiments of the leaves consist, the median of 3 to 4 and the transverse one of 2 to 3 layers of cells. The well marked reticulation of the macrospores is formed of very thin fragile laminæ, not of thick ridges as in some other species.

10. I. HOWELLII, Engelm. n. sp. Middle sized, leaves (10 to 25) bright green (5 to 8 inches long) with thick dissepiments; sporangium oval (1½ to 2½ lines long), unspotted, ¼ to ½ covered by the velum; subulate ligula as long as sporangium; macrospores 0.43 to 0.48 mm. in diam., rough, with prominent rounded single or sometimes confluent tubercles.

On border of ponds at the Dalles of the Columbia, Oregon, *J. & T. J. Howell*, 1880, not quite mature in June. — I insert this species which has just been communicated to me through the kindness of Mr. G. E. Davenport, while the manuscript is in the hands of the printer; this must excuse some discrepancies in the foregoing pages, where no reference could be made to it. The new species is distinguished from the similar *I. Bolanderi* by the longer leaves, larger more prominently marked macrospores, and especially by the distinct peripheral bast-bundles, which place it near the foregoing one, by the thick dissepiment consisting of 4 to 6 layers of cells, and by the unusually narrow and long ligula; the tubercles of the spores are quite prominent, as high as they are wide, rounded at top; microspores light brown, smooth. — Among the specimens of this species, and probably collected with it, I find a single one similar in the structure of the leaf, but without a trace of a velum, the sporangium being entirely naked and only attached by the median line to the leaf base; it is unfortunately immature, and can only be indicated as a probably new species, *I. nuda.* This would not be the first instance of two species growing together in the same pond or lake; in Mystic Pond we find *I. Tuckermani* and *I. echinospora* var. *Braunii*, in Echo Lake the latter and *I. lacustris*, and in Europe not rarely this together with *I. echinospora*.

† † Velum complete.

11. I. FLACCIDA, Shuttleworth, in sched. A slender plant of light green color; leaves often very long, 10 to 35 in number, 15 to 24 inches long, sometimes entirely submerged, or partly floating on the surface, or entirely emerged; sporangia oval, 2 to 3 lines long, entirely covered by the velum; macrospores 0.30 to 0.42 mm. in diam., covered with many or rarely few comparatively large flattish tubercles, distinct or confluent into labyrinthiform wrinkles; microspores not seen. — A. Braun in Flora l. c.; Amer. Jour. l. c.; Chapm. Fl. So. States, p. 602.

Var. RIGIDA, a smaller form with still more slender, erect, dark green leaves (about 10 to 15 in number, 5 to 6 inches long).

Var. CHAPMANI larger, light green, leaves floating (about 30, 18 inches long); sporangium orbicular; spores larger, macrospores 0.44 to 0.55 mm. in diam., marked as the type, or, especially on the upper side, almost smooth; microspores 0.027 to 0.030 mm. long, slightly papillose.

Florida, on the muddy bottom of lakes or swamps, first found by Dr. Rugel in Lake Immonia, north of Tallahassee; lately rediscovered by A. P. Garber in a hummock. near Manatee, on the muddy border of shallow ponds in water from a few inches to 1½ feet deep, the long leaves floating or spread out on the mud, the inner ones erect; mature in April and May, disappearing in June. Var. *rigida* was found by the same collector on the wet borders of Lake Flirt, not far from Lake Okeechobee, in August, entirely emersed and erect. Mr. A. H. Curtiss seems to have met with a similar form in a muddy swamp on Indian river; none of all of these had any mature microspores. Var. *Chapmani* was discovered by A. W. Chapman near Mariana, West Florida, filling a lakelet of pure limestone water about one foot deep, formed by one of those (in that region so common) subterranean streams, where it comes to the surface before emptying into Chipola river, together with *Nasturtium lacustres;* but the *Isoëtes* has not been seen in it since: its larger macrospores, sometimes quite smooth, distinguish it from the other forms. — This peculiar species, the only one thus far found in Florida, is distributed over the whole State. It cannot be classed with the submerged species, for, though evidently often in deep water, the leaves elongate, seek the surface and float on it. The closed velum and the peculiar sculpture of the macrospores readily distinguish it from its allies.

C. Terrestrial species, maturing when entirely out of water, with abundant stomata and peripheral bast-bundles, thick dissepiments, and small air cavities in the nearly triangular leaves.

* Velum partial or almost wanting.

12. I. MELANOPODA, J. Gay. Polygamous; trunk subglobose deeply bilobed; leaves slender, stiff, erect, bright green, usually black at base (15 to 60 in number, 5 to 10 or rarely even 18 inches long); sporangia

mostly oblong (2 to 4 or even 5 lines long), spotted, with narrow velum, ligula triangular-subulate; macrospores among the smallest in the genus, 0.25 to 0.40 in diam., with depressed tubercles often confluent into worm-like wrinkles, or almost smooth; microspores also smaller than usual, 0.023 to 0.028 or rarely 0.030 mm. long, spinulose.—Durieu in Bullet. l. c.; Gray Man. l. c.

Var. PALLIDA. A larger plant, leaf-bases pale, velum usually much broader, covering ¼ or ⅓ of the sporangium; macrospores only 0.30 to 0.35 mm. thick.

An exclusively western species, in low prairies and fields overflowed with at least one inch of water in spring, or in shallow ponds which dry up in summer, in stiff clayey soil, in company with the ordinary vegetation of such localities, e.g. *Nasturtium sessiliflorum*, *Hypericum mutilum*, *Elatine*, *Penthorum*, *Ludwigia*, *Ammannia*, *Alisma*, *Juncus*, etc., from northern and central Illinois, Ringwood, *G. Vasey;* Athens, Menard Co., *E. Hall;* to Clinton, Iowa, *G. Vasey*, the Indian Territory, in low places in the saline flats near Limestone Gap, *G. D. Butler*, and to the wet pine woods in Hempstead Co. and about Houston, Texas, where the variety occurs, *E. Hall.* Maturing in June or beginning of July.— Mr. Hall was accidentally led to the discovery of this plant on his farm in 1853 by finding its trunks and spores in turning up the soil for brick-making; he has since made many interesting observations about it; he does not find it every year, thus in 1877 there was none at all in localities where before and since it abounded, though the season was wet; another time he found it copiously only in plow furrows in a meadow, and none elsewhere; in wet seasons, when the water is deeper than usual about the plants, the leaves become longer, more flaccid, and even decumbent, and the spores mature later or not at all. In ordinary seasons the leaves disappear entirely in July and nothing but the trunks remain, and about them the numerous spores, both of which are eagerly sought after by mice and other animals. The spores germinate whenever sufficient rain falls in the later summer months, and perfect meadows of young plantlets can be observed in wet autumns. Sometimes the plants are seen as fresh in September as in May, and already 4 to 6 inches high, and in 1865 they were so much favored by the season that a second crop was gathered in November with perfectly mature spores; but it is scarcely probable that these could have been seedlings of the preceding summer, though Mr. Hall is inclined to think so.

The polygamous character of this species has been alluded to on page 363. I will here only add, that a number of monœcious specimens show a preponderance of one or the other sex, and that in a few I have found leaves, which bear male or female sporangia, irregularly mixed.

The dissepiments of the leaves consist of 6 to 9 layers of cells, the lower median being the thickest. Besides the normally 4 peripheral bast-bundles we find here often several smaller accessory ones, which increase the rigidity of the leaves. In no species have I seen the macrospores so variable

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

in size in the same sporangium; large and small ones are indiscriminately mixed; and they are also remarkably variable in their sculpture, showing distinct or confluent vermiculate tubercles, or a nearly smooth surface; the dividing ridges or commissures are very prominent and smooth. The leaf-bases of the typical form of this species are black and shining, and justify the name given by that zealous botanist, Jacques Gay, who in his 75th year was still anxious and able to climb the high mountains in the centre of France, to study in their lakes the two European species which had just then become prominent through the labors of his friend Durieu de Maisonneuve, and who left us such a vivid description of his hardships, excitements and pleasures on that trip (Bull. S. B. F. vols. 8 & 9); death prevented him from publishing it, but his name remains connected with it. Now and then a paler specimen is seen, and the Texan form is always pale, and distinguished also by its broader velum.

13. I. BUTLERI, Engelm. Diœcious, smaller than the last, with a subglobose trunk and thinner and more rigid bright green leaves, 8 to 12 in number and 3 to 7 inches long; sporangium usually oblong, spotted, without any or with a very narrow velum; ligula subulate from a triangular base; macrospores larger than in last, 0.50 to 0.63 mm. in diameter, similarly marked with knobs or warts, distinct or sometimes confluent; microspores 0.028 to 0.034 mm. long, dark brown, papillose. — Bot. Gazette, 1878, p. 1.

Var. IMMACULATA. Larger, leaves sometimes as many as 60, 6 to 9 inches long; sporangium without spots; macrospores rather smaller, 0.40 to 0.56 mm. in diam.; microspores 0.029 to 0.031 mm. long, spinulose.

In the saline flats (called alkali flats, but impregnated with sulphates) of the Indian Territory, near Limestone Gap, between Arkansas and Red rivers, associated with the few coarse plants which can live in those localities overflowed in winter and spring, and baked hard in summer and autumn, such as *Iva angustifolia*, *Ambrosia psilostachya*, *Arenaria Pitcheri*, and with *Isoëtes melanopoda*, but in rather drier localities than this; maturing in May and June, *G. D. Butler*. The variety near Nashville, Tenn., in cedar barrens, in damp places on the limestone flats, with *Leavenworthia*, *Talinum*, *Sedum pulchellum*, *Schœnolirion*, several *Junci*, etc., *A. Gattinger*.—This species, also peculiar to the Mississippi Valley, is quite unique in this genus by its dioicity, though its nearest ally, the last mentioned one, approaches it. From this it is readily distinguished by the absence of the velum, by the deep brown color of the microspores and the larger size of the macrospores; in these last I notice the peculiarity that the ridges themselves which separate the faces of the spores are also more or less tuberculated, while in other species they are quite smooth.

* * Velum complete.

14. I. NUTTALLII, A. Braun in Herb. Similar to the last two species, with an almost globose slightly grooved trunk and 20 to 60 slender bright green leaves, 3 to 9 inches long, with only 3 peripheral bast-bundles; spo-

rangium oblong or oval, entirely covered by the velum; macrospores very variable in size, between 0.25 and 0.50 mm. thick, densely covered with minute but prominent rounded warts, or, rarely, almost smooth; microspores 0.025 to 0.028 mm. long, papillose, brown. — Engelm. in Am. Nat. 8, p. 215; *I. opaca*, Nutt. in Hb. Ac. Phil.

On damp prairie flats or springy declivities in the valley of the Columbia river, *Nuttall;* abundant about Silverton in the Wallamette valley, *E. Hall*, No. 693; at Milwaukee, Oregon, *J. Howell* (with almost smooth macrospores); Klickitat Co., Washington Terr., on Kamass Prairie and at the base of Mt. Adams, 2,100 feet alt., *W. N. Suksdorf;* eastward on Kamass Prairie of the Cœur d'Aleines in Western Idaho, *Ch. A. Geyer*.— The closed velum and the much smaller warts of the macrospores distinguish this readily from the two other terrestrial speeies; it is the only species on which I observe constantly only 3 peripheral bast-bundles, one on each of the three edges, the upper middle one being absent. The median dissepiment of the leaves consists of 8 or 9 and the transverse one of 6 to 7 layers of cells.

II. **Trunk trilobed,** bast-bundles and numerous stomata in the quadrangular leaves; velum partial.

15. I. Cubana, Engelm. One of the larger species; leaves 30 to 40, 15 inches long, fresh green, with 6 bast-bundles; sporangia oblong, unspotted; velum very narrow; macrospores 0.30 to 0.40 mm. thick, marked with coarse round depressed, never confluent tubercles; microspores 0.024 to 0.027 mm. long, papillose, pale.—Sauvalle Fl. Cub., p. 203, name only.

On the bottom of rivulets in the pine woods of Eastern Cuba, *Chas. Wright*, probably floating. — This is the only American species north of the Equator with a trilobed trunk; it compares most closely with the East Indian *I. Coromandelina* according to A. Braun's observation. The roots form 3 distinct bundles from the 3 grooves; the bast-bundles are found at the four intersections of the dissepiments with the outer walls and at the two upper edges of the leaf.

TABULATED CHARACTERS OF THE NORTH AMERICAN ISOËTES.

	Vegetation.	Trunk lobes.	LEAVES.		Stomata.	Bast-bundles.	Velum.	Sporangium.	MACROSPORES.		MICROSPORES.		NATIVE COUNTRY.
			Number.	Length inches.					Diameter, millimeters.	Surface.	Length, millimet.	Surface.	
1. *I. lacustris*	subm.	2	10—25	2— 6	0	0	*n.*	*w.*	0.60—0.80	Cristate	0.035—46	Smooth	North'n N.York to Lake Sup'r
var. *paupercula*	"	2	10—18	2— 4	"	0	*b.*	*w.*	0.62—0.66	"	0.026—36	Nearly do.	Rocky Mountains & California
2. *I. pygmæa*	"	2	5—10	½— 1	0	0	*n.*	*w.*	0.36—0.50	Minutely tuberculated	0.024—29	" "	Californian Mountains.
3. *I. Tuckermani*	"	2	10—30	2— 3	0	0	*b.*	*sp.*	0.44—0.56	Cristate above, reticulate below	0.026—32	Smoothish	New England.
4. *I. echinospora*													
var. *Braunii*	"	2	15- 30	3— 6	few	0	*b.*	*sp.*	0.40—0.50	Spinulose	0.026—30	Smooth	Pennsylvania northward and northwestward and to Utah.
var. *robusta*	"	2	25—70	5— 8	many	0	*b.*	*sp.*	0.35—0.55	With longer slenderer spines	0.026—31	Smooth	New England.
var. *Boottii*	"	2	12—30	4— 5	few	0	*bb.*	*sp.*	0.40—0.50	" " "	0.026—30	Smoothish	
var. *muricata*	"	2	15—30	6—12	"	0	*bb.*	*w.*	0.44 0.58	With shorter confluent spines	0.028—32	"	" "
5. *I. Bolanderi*	"	2	5—20	2— 4½	"	0	*b.*	*w.*	0.30—0.45	Sparsely and minutely tuberculated	0.026—31	Papillose	Calif., Oreg., Rocky Mount'ns.
6. *I. saccharata*	amph.	2	10—20	2— 3	many	0	*n.*	*sp.*	0.40—0.47	Minutely tuberculated	0.024—25	"	Maryland.
7. *I. riparia*	"	2	15—30	4— 8	"	0	*b.*	*sp.*	0.44—0.65	Cristate	0.028—34	"	Pennsylvania to NewEngland.
8. *I. melanospora*	"	2	5—10	2 - 2½	"	0	*c.*	*w.*	0.35—0.45	Minutely tuberculate	0.027—30	Smoothish	Georgia.
9. *I. Engelmanni*	"	2	25—100	9—20	"	4	*n.*	*w.*	0.40 - 0.52	Reticulated	0.024—28	"	Delaware to N.Eng.&Missouri.
var. *gracilis*	"	2	8— 12	9-12	"	4	*n.*	*w.*	0.38—0.48	"	0.024—28	"	Pennsylvania to New England.
var. *valida*	"	2	50—200	18—25	"	4	*b.*	*w.*	0.32—0.48	"	0.024—27	Spinulose.	Pennsylvania.
var. *Georgiana*	"	2	15	10—12	"	4	*n.*	*w.*	0.48—0.56	"	0.028—31	Smooth	Georgia.
10. *I. Howellii*	"	2	10—25	5— 8	few	4	*b.*	*w.*	0.43—0.48	Coarsely tuberculated.			Oregon.
11. *I. flaccida*	subm.?	2	10—35	15-24	many	4	*c.*	*w.*	0.30—0.42	Coarsely tuberculated, tub. often confluent			Florida.
var. *rigida*	amph.	2	10—15	5— 6	"	4	*c.*	*w.*	0.30—0.38	" " "			"
var. *Chapmani.*	"	2	30	18	"	4	*c.*	*w.*	0.44—0.55	" often smooth above	0.027—30	Papillose	"
12. *I. melanopoda*	terr.	2	15—60	5—16	"	4+	*n.*	*sp.*	0.25—0.40	" " " "	0.023—30	Spinulose.	Illinois to Indian Territory.
var. *pallida*	"	2	10—15	8- 15	"	4	*b.*	*sp.*					Texas.
13. *I. Butleri*	"	2	8—12	3— 7	"	4	*nn.*	*sp.*	0.50 0.63	Minutely tuberculated	0.025—31	Papillose	Indian Territory.
var. *immaculata*	"	2	20—60	6— 9	"	4	*nn.*	*w.*	0.40 - 0.56	do. or nearly smooth	0.029—31	Spinulose.	Tennessee.
14. *I. Nuttallii*	"	2	15—60	3— 9	"	3	*c.*	*w.*	0.32—0.52	Minutely tuberculated	0.025—28	Papillose	Western Idaho to Oregon.
15. *I. Cubana*	amph.?	3	30—40	15	"	6	*n.*	*w.*	0.30—0.40	Coarsely tuberculated.	0.024—27	"	Cuba.

EXPLANATIONS.

VEGETATION — submerged, amphibious, or terrestrial.

VELUM — *n* means narrow; *nn*, very narrow: *b*, broad; *bb*, very broad; *c*, closed.

SPORANGIUM — *w* means white or unspotted; *sp*, spotted with dark sclerenchym-cells.

MISSOURI BOTANICAL GARDEN
GEORGE ENGELMANN PAPERS

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI
BOTANICAL
GARDEN

THE GENUS ISOËTES IN NORTH AMERICA.

By DR. GEORGE ENGELMANN.

From the Transactions of the St. Louis Academy of Science. Vol. IV., No. 2.

Read February, 1882.

0 1 2 3 4 5 6 7 8 9 10
cm
copyright reserved
MISSOURI
BOTANICAL
GARDEN

14859

The Genus ISOËTES *in North America.*

By Dr. GEORGE ENGELMANN.

§ *1. History of* ISOËTES *in North America.*

The *Isoëtes*, insignificant and apparently sterile as they are, were long overlooked or ignored by our botanists, so that until thirty or forty years ago very few specimens were collected, and none were distinguished from *I. lacustris*, if we except Nuttall's guess at his Oregon discovery; but the genus has attracted so much attention, and lately so many forms have become known, that it seems to me an interesting task to trace up the history of the discovery of the different species and their varieties, and of the area of their distribution, and then the date of their publication, before I enter into their scientific description.

I. DISCOVERY.

1806 (?). The first notice which we have of an *Isoêtes* in North America is given in Pursh's Flora, ii. 671, where he states that "*Isoëtes lacustris*" grows in the bottom of Oswego river, near the falls, and adds his *v. v.*, which means that he saw it living, and therefore probably found it himself; and as he travelled through the regions near the Great Lakes in 1806, it was probably in that year that he met with it. I have not seen Pursh's specimens, but doubt not but that it will have to be referred to *I. echinospora*, var. *Braunii*, the only form thus far known from Western New York.

1815. Th. Nuttall collected "*I. lacustris*," abundant along the inundated gravelly and miry shores of the Delaware at Gibsonville (now a part of Philadelphia) on Aug. 22d, according to the label of a specimen in Collins' Herbarium, presented to me by E. Durand. It proves to be *I. riparia.*

1820 (?). L. von Schweinitz obtained in the Catskill Mountains in New York *I. lacustris;* some of his specimens are now found in the Herb. Philad. Acad. Natural Science and one in the St. Petersburg Imperial Herb. Some of them are labeled "Catskill Mountains" and others "Bethlehem," the latter, which was von Schweinitz's residence, probably by mistake. One of the specimens was loaned by the late Elias Durand—in whose possession it was—to Durieu de Maissonneuve, who founded on

MISSOURI BOTANICAL GARDEN
GEORGE ENGELMANN PAPERS

it his I. MACROSPORA. No date being indicated on the labels, the above-mentioned year is a mere guess.

1825 (?). Jens Vahl collected in Greenland a small *Isoêtes*, referred to *I. lacustris*, which proves to be one of the forms of *I. echinospora*.

1831. J. W. Robbins gathered an *Isoêtes* near Uxbridge, Mass., which I recognize as *I. riparia*.

1832. C. J. Moser, who collected for the German *Unio itineraria*, obtained specimens on the Lehigh river near Bethlehem, Pa., and near Philadelphia, both of which were distributed to the subscribers as *I. lacustris*. One of these (in Herb. Bernhardi, now in the Herb. Missouri Bot. Garden) represents *I. Engelmanni;* another, which I have seen in Europe, is *I. riparia*.

1834. Th. Nuttall discovered an *Isoëtes* on the Columbia river in Oregon, which I saw in E. Durand's Herb. with Nuttall's own label, *I. opaca ;* it was afterwards named I. NUTTALLII.

About the same year Drummond collected "*I. lacustris*" on the Saskatchawan, according to Hooker's Fl. Bor. Am. ii. 268, which I have not been able to compare and to identify.

1840. J. W. Robbins found *I. lacustris* near Uxbridge.

1842. Rugel discovered an *Isoëtes* in Lake Imonia in Florida, which was soon afterwards distributed in Europe by Shuttleworth under the name of I. FLACCIDA. None of his specimens are believed to exist in America.

In the same year N. Riehl and myself found near St. Louis, Missouri, the species which from my specimens was by A. Braun named I. ENGELMANNI.

1843. Chas. Geyer found in Western Idaho *I. Nuttallii*, according to A. Braun, who examined the specimens in the Kew Herbarium.

In the same year S. Tuckerman collected *I. lacustris* in the Echo lake in New Hampshire.

1844. Wm. Zantzinger rediscovered the *Isoëtes* on the banks of the Delaware near Philadelphia. His specimens, sent to me, are the type of my I. RIPARIA.

1845. T. W. Robbins found in Massachusetts *I. echinospora*, var. *Braunii*.

1848. E. Tuckermann discovered near Boston the species which was by A. Braun named for him I. TUCKERMANI.

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

1850. A. W. Chapman found in Northern Florida a peculiar *Isoëtes*, which proved to be a large-spore form of *I. flaccida*, and was named var. CHAPMANI.

1853. E. Hall discovered in his fields near Athens in Central Illinois the species which was afterwards named by J. Gay I. MELANOPODA.

1856. I found *I. echinospora*, var. *Braunii*, in Lake Winnipiseogee in New Hampshire, the type of I. BRAUNII, Durieu.

1857. E. D. Eaton obtained *I. Engelmanni* for the first time in the New England States.

1860. Wm. Boott found near Boston the form of *I. echinospora*, which was named from his specimens I. MURICATA by Prof. Durieu, the present *I. echinospora* var. *muricata*.

1862. Th. C. Porter discovered near Lancaster, Pa., the largest American *Isoëtes*, *I. Engelmanni*, var. VALIDA.

In the same year G. Vasey found *I. melanopoda* in Iowa.

1863. I. Macoun obtained *I. echinospora*, var. *Braunii*, in West Canada.

In the same year Wm. M. Canby discovered in Maryland I. SACCHARATA.

1865. Leidy and Porter collected *I. lacustris* near the outlet of Lake Superior.

In the same year *I. Tuckermani* was rediscovered near Boston by Wm. Boott.

1866. Chs. Wright discovered I. CUBANA in Eastern Cuba.

In the same year H. Bolander found two new species in the Sierra Nevada of California, I. BOLANDERI and I. PYGMÆA.

1867. Wm. Boott got near Boston the species named after him I. BOOTTII, now known as *I. echinospora*, var. *Boottii*.

1869. Wm. M. Canby discovered on the Stone Mountain in Georgia the curious little I. MELANOSPORA.

In the same year S. Watson found *I. echinospora*, var. *Braunii*, in Utah.

1871. E. Hall gathered beautiful specimens of *I. Nuttallii* on the Columbia river.

1872. The same traced *I. melanopoda* to Texas.

1873. T. P. James got *I. echinospora*, var. *Braunii*, in Nova Scotia and C. C. Parry found *I. Bolanderi* in Yellowstone lake in Wyoming.

1875. G. D. Butler discovered in the Indian Territory the species named for him I. BUTLERI, and with it a new locality for *I. melanopoda.*

1878. C. G. Pringle found in Lake Champlain the form of *I. echinospora*, which I have designated as var. ROBUSTA.

1879. M. E. Jones met with *I. Bolanderi* in Utah.

1880. A. Gattinger discovered near Nashville, Tennessee, a *I. Butleri*, var. IMMACULATA.

1881. I collected *I. lacustris* var. PAUPERCULA in Grand Lake, Middle Park, Colorado, and C. G. Pringle found the same in Northern California.

2. PUBLICATION.

1753. Linnæus published in his *Species Plantarum*, ed. i., his *Isoëtes lacustris*, the only species known to him.

Neither Michaux nor any of the older writers on American plants knew of any North American *Isoëtes.*

1816. Pursh, Fl. Am. Sept. ii. 671, mentions "*I. lacustris*" from Oswego river, Western New York, which is most probably *I. echinospora*, var. *Braunii*, the only species thus far known from that region.

1818. Nuttall, Gen. ii. 253, has "*I. lacustris*" from the miry shores of the Delaware near Philadelphia, which cannot be any other than *I. riparia ;* he also gives Pursh's habitat.

In the same year Barton, Fl. Philad. ii. 213, has "*I. lacustris*" from Philadelphia, which may include both *I. riparia* and *I. Engelmanni.*

1824. Elliott knows no *Isoëtes.*

1826. Torrey (Comp. Fl. North. & Middle States) gives as habitat of "615, *I. lacustris*," bottoms of lakes, evidently without having himself seen it.

In the Flora Cestrica of the same year Darlington does not mention the genus.

1827. Sprengel, Syst. Plant. iv. 9, knows only *I. lacustris* with three varieties.

1833. Beck in his Botany repeats Pursh's and Nuttall's localities.

1840. Hooker, Fl. Bor. Am. ii. 268, mentions "*I. lacustris*" from the Saskatchawan. This may be the true *lacustris* or a

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

form of *echinospora*, either of which may be expected in those regions.

1843. Torrey, Flora of New York, ii. 514, "*I. lacustris*," a mere repetition of Pursh's statement.

1844 Bory investigates the Genus, which until then had been very much neglected, and adds to the three then known species (*I. lacustris*, *Coromandelina*, and *setacea*) three new ones discovered in Algeria by Durieu de Maissonneuve.

1846. A. Braun, in Regensburg bot. Zeitung, No. 12, briefly characterizes *I. riparia*, Engelm., from Philadelphia; *I. Engelmanni*, A. Br., from Missouri, and *I. flaccida*, Shuttlew., from Florida.

1847. The Amer. Journ. Arts & Sciences, n. ser. iii. 52, publishes a translation of the above notice.

1848. A. Gray, in the first edition of the Manual Bot. North. States, p. 640, distinguishes the then known three northern species, *I. lacustris*, *I. riparia*, and *I. Engelmanni*.

1853. Darlington, Fl. Cest. ed. ii. p. 402, mentions "*I. lacustris*" as growing in shallow ponds in his district. This must refer to *I. Engelmanni*, the only species growing there in such localities.

1856. A. Gray, Manual, ed. ii., gives an almost verbal reprint of the first edition.

1860. Chapman, Fl. South. States, p. 602, describes *I. flaccida* as growing in "lakes and clear streams" in Middle and West Florida.

In the same year E. Tatnall, Cat. Pl. Newcastle Co., Delaware, enumerates *I. riparia* and *I. Engelmanni*, both of which names here probably stand for the latter.

1861. Durieu de Maisonneuve, Prof. of Botany at Bordeaux, in Bull. Soc. Bot. France, viii. p. 164, distinguishes and characterizes the two North European species *I. lacustris* and *I. echinospora*, heretofore thrown together.

1864. The same author, l. c. 101, 102, indicates four American *Isoëtes*: *muricata* from Massachusetts, *Braunii* from New Hampshire, *macrospora* from the Catskill Mountains, and *melanopoda* Gay (or Gay and Durieu) from Illinois.

In the same year A. Braun published a most important treatise on the Genus in his account of the *Isoëtes* of the Island of Sardinia, in which our species are frequently referred to.

1867. In the fifth edition of Gray's Manual, p. 676, I for the first time published *I. echinospora* as an American species, differing in several varieties from the European type—var. *Braunii* (*I. Braunii*, Dur.), var. *muricata* (*I. muricata*, Dur.), and var. *Bootti* (*I. Boottii*, A. Braun in lit.), all of them from the North-eastern States; also *I. Tuckermanni*, A. Braun in lit., from Massachusetts, and *I. saccharata*, Engelm., from Maryland.

1874. In Dr. Parry's Botanical Observations in Western Wyoming, Am. Naturalist, viii. 214, 215, I gave an account of the three western species: *I. Bolanderi*, Engelm.; *I. pygmæa*, Engelm., and *I. Nuttallii*, A. Br. in lit.

1877. My notice of *I. melanospora*, Engelm., from Georgia was published in the Trans. Acad. Sci. St. Louis, iii. 395, note.

1878. In Coulter's Botan. Gazette for January, p. 1, I gave an account of *I. Butleri*, Engelm., found in the Indian Territory west of Arkansas.

§ 2. *Morphology of Isoëtes.*

The species of *Isoëtes* are the simplest vascular plants known. They consist of a short trunk* with root-fibres at its base and leaves on its top, normally withoul branching and without any axillary productions.†

The TRUNK is generally depressed, broader than high, or flatter in some species (*I. Engelmanni*), and thicker and more globose in others (*I. melanopoda*), but its form is not constant; it is concave on the upper side and even somewhat funnel-shaped where the leaves are inserted, while the underside shows in almost all the N. American species two grooves and in many exotic ones three grooves, dividing the trunk more or less deeply into two or into three lobes. The number of lobes rarely varies, so that among the many hundreds and even thousands of American specimens which have passed through my hands, I have found only a single, normally bilobed, one with three lobes; this was an *I. riparia* from Philadelphia. In the 3-lobed species the transverse section is rather circular, but in the 2-lobed ones it is usually oblong or often somewhat rectangular, narrower in the direction of the grooves and wider in the opposite direction; the vertical section of the trunk shows a thickness of from 1 to 6 lines, and the transverse diameter a width of a few lines to more than one inch. In the centre of the trunk we find a small ligneous body, fibres from which enter the leaves and the roots. The mass of the trunk is a white parenchymatous or rather cortical tissue, the cells of which are filled with starch. The growth proceeds from the central ligneous body outwardly in two or three directions, corresponding to the two or three lobes, so that these lobes would spread laterally if their enlargement were not limited by the decay of the older (the preceding year's?) parts. We thus find that at the period of the most vigorous growth, about the beginning of fructification, the extreme lateral portion of the lobes becomes discolored, brownish, atrophied, and at last black, and is separated from the living tissues by a distinct line of demarcation, and at last generally falls off at the end of this or the beginning of the next season as a black mould-like mass. In some species, e g. *I. lacustris*, and in colder climates the atrophied cortical parts continue to cohere for several seasons, and in the Mediterranean *I. Hystrix* they do not seem ever to be detached, so that the trunk of this species reaches a larger size than any other.

---

* A very complete account of the structure of the trunk is given by H. Mohl in Linnæa xiv. (1840) 181, and of the whole plant and its morphology by A. Braun in the *Isoëtes* der Insel Sardinien. Monatsber. d. Berliner Acad. Wissensch. 1864.

† Abnormally the *Isoëtes* trunk has been seen divided, probably in consequence of some injury; I myself have seen a specimen of *I. Tuckermani* with four distinct bunches of leaves from a single trunk. K. Goebel found a proliferous *Isoëtes* with lateral shoots in place of spore cases. Bot. Zeitung, 1879, No. 1.

The decaying portions are pushed obliquely upwards when the base of the trunk grows faster than the upper part (often in *I. Engelmanni*, and much more so in the Australian *I. tripus*), or horizontally outward (the ordinary case), or downward when the upper or leaf-bearing part expands more than the lower, root-bearing part. This last is the case in *I. Hystrix*, where the dead parts are turned downwards.

As the growth of the trunk takes place from the centre outward, the roots, originating from the youngest parts, start from the groove itself; and fresh and living, whitish, ones are only found in or near this groove: as they get older they are pushed to the sides, and finally die, becoming brown and black. The mass of roots found on *Isoëtes* specimens are mostly the entangled dead fibres, which, by the way, often conceal spores of the previous year, and therefore must be carefully examined when no fresh spores are attainable. The root-fibres, sometimes longer than the leaves, are always dichotomously, and often many times, branched. — The upper, concave, surface of the trunk bears the leaves, the innermost or youngest ones often yet immersed in the trunk.

The LEAVES are subulate or sometimes almost filiform tubular organs from a broad membranaceous sheathing base, mostly more or less quadrangular (broader and with sharper edges on the upper or ventral, narrower on the dorsal side), or in our terrestrial species more triangular and keeled on the back. Their sheathing bases form the *bulb*, which can be compared to the bulb of liliaceous plants; in fertile specimens it is always larger and thicker than the trunk, and in some of the larger ones, e.g. *I. Engelmanni* and *I. melanopoda*, attains a diameter of one or two inches. The leaves above this base contain four longitudinal air cavities, *lacunæ*, separated from one another by two dissepiments, a transverse and a median one, and irregularly divided by very thin transverse *septa*. The dissepiments are of different, pretty constant, thickness in the different species, thinnest in the amphibious and thickest in the terrestrial species, consisting in the former often of only 2 to 4, in the latter of 6 to 9 layers of parenchymatous cells; the median dissepiment is generally a little thicker than the transverse one. The anterior *lacunæ* are mostly somewhat larger than the posterior ones.

The epidermis of the leaf consists of rectangular cells, mostly much longer than they are wide; only in *I. pygmæa* are they comparatively short, and sometimes even square. In a few species the epidermis is entirely destitute of stomata, in the others it is pierced by stomata which communicate with the air-ducts, over which alone they are found. The presence or absence of stomata furnishes a very important character for the diagnosis and classification of the species. It was formerly thought that the submerged species had no stomata, and those species which bear their leaves more or less exposed to the air were provided with them; later discoveries, however, have shown that this rule does not always hold good, for we now know submerged species with stomata and emerged ones without them, and we have one submerged species (*I. echinospora*) in which the typical European form is destitute of stomata, while the American varieties show

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

either a few stomata, often difficult to discover, or, rarely, numerous ones; so that in this interesting species the question arises whether the presence or absence of stomata *alone* can specifically separate forms otherwise scarcely distinguishable, as that acute observer of these plants, A. Braun, has maintained, or whether the stomata do *not* always play that important part in classification generally assigned to them. Below will be found directions for the investigation of the stomata.

The parenchyma of the leaf consists of a few or several layers of chlorophyll-bearing cells, 1. under the epidermis, 2. around the central bundle of vessels, and 3. forming the dissepiments, which cross each other in the centre of the leaf.

An important element in the leaf structure is found in the peripheral bast-bundles, which are present in some and absent in other species; and their presence often, but not always, coincides with the presence of stomata. When present they commonly form four bundles, two in the two anterior angles of the leaf, and two where the median dissepiments connect with the anterior and the posterior wall of the leaf; in *I. Nuttallii* I find only three bundles, the anterior median one being wanting; in *I. Cubana* six bundles are visible, the two additional ones being located where the transverse dissepiment unites with the outer wall. In some rigid-leaved land species, e.g. *I. melanopoda*, often several smaller accessory bundles are found scattered under the epidermis.

The examination of the fresh *Isoëtes* leaf is not very difficult; particles of the epidermis are easily removed and show the stomata, when present, very distinctly. Where there are few stomata, the epidermis from different parts of the leaf must be examined, and especially from the tip, as they are more apt to be found there. In dried specimens the leaf must be soaked, the *algæ* which often adhere to the surface have to be carefully scraped off, after which I make several sections ¼ or ½ line wide, lay them open by a vertical slit, detach the central bundle, and then scrape very gently the inner surface so as to remove the parenchymatous cells which obscure the appearance of the stomata This process can be aided by an immersion of the specimen in a weak solution of caustic potash. The work is often a difficult one when the specimen is very old or poorly preserved, and requires a good deal of patience. Sometimes the application of iodine will very distinctly show the stomata by coloring their guard-cells blue when only these contain amylon, but of course not when the other cells are also filled with that substance. A magnifying power of 150 to 250 diameters is best adapted to well exhibit the stomata.

To find the bast-cells it is necessary to make the thinnest possible transverse sections of the leaf, boil them well, and, if they do not then show under water as bundles of minute, thick-walled, darkish cells close to the epidermis, very distinct from the much larger epidermis cells, the application of a solution of caustic potash, to clear the preparation, will readily bring them out. The same magnifying power which we use for the examination of the stomata may be applied for the study of the bast-bundles.

I would advise anyone who desires to study the structure of *Isoëtes* leaves to commence with well known species and good (if possible fresh) specimens, and make himself familiar with the manipulation and with the appearance of their parts under the microscope before he proceeds to study unknown and difficult specimens.

The arrangement of the leaves in the species with two-lobed trunks is at first distichous, and in *I. melanospora* it remains so through life; in all the others the leaves soon enter into a more complicated phyllotactic order; in the larger ones, with many leaves the $\frac{13}{21}$ and even the $\frac{21}{34}$ order is found.

The number of leaves varies from 5 or 10 (*I. pygmæa*, *I. melanospora*) to 100 or even 200 (*I. Engelmanni*, var. *valida*), and their length from ½ to 1 inch (in *I. pygmæa*) to 1–2 feet (in some forms of *I. flaccida* and *I. Engelmanni*); their color from light and fresh yellowish-green (*I. Engelmanni*) to dark and dull green *I. lacustris*); their rigidity is greatest in the terrestrial species, and also in some submerged ones; and least in most amphibious species, which often float their leaves on the surface of the receding water, or in some submerged ones, the leaves of which, taken out of the water, collapse like the soft hair of a wet pencil. The submerged species vegetate and retain their verdure throughout the winter (whence, it is said, the name of the genus is derived: *Isoëtes*, equal at all seasons), but the others lose their

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

leaves soon after their maturity in autumn, some of our terrestrial ones even already in summer.

The broad membranaceous sheathing base of the leaf is without air cavities, stomata, or bast-bundles; in sterile leaves it gradually contracts into the leaf itself. Those leaves are usually sterile which develope at the beginning and the end of the season. The fertile leaves have in their base an excavation which bears the spore-case, *sporangium*, adnate with its back to the midrib. Above this excavation, and separated from it by a deep transverse depression or slit, we find a stipule-like organ of triangular more or less elongated shape, cordate at base, appressed to the leaf, which is termed the *ligula;* it is small, and in not very fresh leaves often mutilated and difficult to make out. The morphology of these parts is obscure and their diagnostic value not great.

The sporangium is oblong or circular (both forms often seen in the same species), from ½ to 1 line long in *I. melanopoda*; 1 to 2 lines in *I. pygmæa*, *Tuckermani*, *echinospora*, and *saccharata;* 1½ to 2½ lines in *I. lacustris*, *Bolanderi* and *flaccida;* often a little larger in *I. Butleri* and *Nuttallii;* 2 to 4 lines in *I. riparia*, *Engelmanni*, *melanopoda*, and *Cubana;* and in larger forms of *I. Engelmanni* I have seen it 8 to 9 lines long. It is somewhat flattened, and often slightly concave on the ventral side; it is entirely naked or (the usual case) it is on its sides and principally upwards partially covered by a fold of the ventral side of the leaf-base, the veil (*velum*); in a few species (*I. flaccida*, *melanopoda*, and *Nuttallii*) this fold extends over the whole sporangium, completely covering it (*velum completum*). The sac of the sporangium is composed of two layers of cells; the outer, epidermidal, layer consists of elongated, often variously bent or hooked and curiously interlaced cells, mostly thin-walled and transparent; in some species (e.g. *I. riparia*, *I. saccharata*, *I. melanopoda*) groups of brown, thick-walled, (so-called) sclerenchym-cells are mixed with the transparent ones, giving the spore-case a dotted appearance visible even to the naked eye. The spore-case is traversed by numerous parallel strings.

Some sporangia, called *macrosporangia*, contain larger or female spores (*macrospores* or *gynospores*), others are filled with the minute or male spores (*microspores* or *androspores*); these are called *microsporangia*. Almost all the species are monœcious, bearing macrosporangia on the base of the outer and microsporangia on that of the inner leaves. I am not aware that any exotic species behave differently, but here we have two species which deviate from this norm. *I. melanopoda* in Illinois as well as in the Indian Territory, from both of which localities I have examined several hundreds of specimens, is polygamous, i.e. monœcious as well as diœcious, and shows about an equal number of male, female, and monœcious plants. The allied *I. Butleri* is apparently always diœcious, no monœcious plants having been discovered among about one hundred examined. In *I. melanopoda* I have sometimes seen leaves with microsporangia irregularly interspersed among those that bear macrosporangia.

The macrospores are little spheroid bodies between one-fourth and three-fourths of a millimeter in diameter. Their surface is divided by a circular rim in a lower hemispherical and an upper three-sided pyramidal part, the three faces of which consist of spherical triangles and are separated from one another by three elevated ridges. The crusty surface of these spores, chalky-white or whitish in most species and dusky (when wet black) in *I. melanospora*, is rarely smooth, but generally sculptured and differently marked. The three upper triangles are sometimes marked differently from the lower hemisphere (especially in *I. Tuckermani*) or are smoother than that (often in *I. melanopoda*). To examine the spores well it is necessary to soak the leaf-base, carefully remove some of the wet spores and let them dry on the slide, for they must be examined dry, and best under a power of 50 or 60 diameters; but, to study the sculpture well, a power of 100 to 150 diameters is necessary. With the aid of this we find the macrospores—1. Minutely tuberculated or warty; the warts small and mostly somewhat depressed, distinct or sometimes somewhat confluent, in *I. pygmæa*, *Bolanderi*, *saccharata*, *melanospora*, *Butleri*, and *Nuttallii*.

2. With larger, broader tubercles, generally more distant and distinct, but also here and there confluent, worm-like; thus in *I. flaccida*, *melanopoda*, and *Cubana*.

3. With tubercles elongated into spines; these are simple and very fragile, or here and there confluent and forming sometimes short crests: *I. echinospora* and its forms.

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

4. With crests and ridges, distinct or anastomizing: *I. lacustris*, *Tuckermani*, and *riparia*.

5. The confluent crests form a regular net-work: *I. Engelmanni*.

The microspores are minute bodies of an ash-gray or a dusky color (dark gray in *I. pygmæa*, *Bolanderi* and *melanopoda*, deep brown in *I. melanospora*, *Butleri* and *Nuttallii*) and of a somewhat triangular-oblong shape, nearly straight on one and curved on the two other edges, more than half as wide as they are long, between 0.020 and 0.040 millimeters in the longest diameter. Their surface is smooth or minutely papillose or spinulose, the edges smooth or somewhat cristate. Their size furnishes good characters, but the condition of the surface much less so. They ought to be examined under water and with a power of about 400 diameters.

§ 3. *Biological Characters.*

After the maturity of the spores the leaves wither or rot away, the sporangia decay and set the spores free, which scatter near the base of the plant, often being retained between the matted roots.* The cellular mass of the macrospores developes into a *prothallus*, which bursts the spore-case through the opening of three valves which correspond to the three upper faces of the spore, and forms an archegonium, which is fertilized on coming in contact with the zoöspores emitted from the microspores, and thus gives rise to the young plantlet whenever moisture and temperature favor this process.

The germination of the late-maturing water-species probably takes place in the succeeding spring, at least in the more northern localities; in our land- and marsh-species it may be observed soon after their maturity in summer or in early autumn.

I have studied the whole process in *I. Engelmanni*, which I kept in cultivation for several years. At the end of July the spores were perfectly mature and the leaves were coming off. On the 28th of that month I spread out both kinds of spores on a muddy surface and kept them slightly covered with water, and fully exposed to the hot sunshine of that season. Three weeks later the first green points were seen and continued to come up until the end of October, while at that time the earlier ones had already developed 5 to 8 leaves, ½ to 1½ inches in length. The contents of the large or female spore-cell first developed into a dense cellular mass; this, enlarging, split the cell-coats as above described and protruded obliquely upwards a minute conical point, green inside, while on the lower edge of the opening, but still between the three valves (the lower hemisphere of the spore-case not being ruptured or perforated at all), a much smaller and rounded knob, the origin of the first rootlet, showed itself, bearing a large number of extremely fine capillary fibres; the bulk of the prothallus remained enclosed in the hemispherical part of the spore-case as a lateral knob, while the first leaf and then the first rootlet elongated; the spore-case was thrown off only when the former had acquired a length of 3 to 4 and the latter one of 2 to 3 lines, the capillary fibres still continuing at the origin of the rootlet. Soon afterwards a second leaf and a second rootlet were formed, both opposite to the laterally protruding spore-mass; after that new leaves and new roots spring up in distichous order between the older ones, the youngest in the centre. In twelve months the young plant, not yet fertile, shows the bilobed flat or rather concave trunk, 2 to 4 lines in diameter, with both ends strongly elevated, their edges already showing small masses of black decayed tissue (the remnants of the first year's growth). The leaves of these yearling plants, 10 to 15 in number, are 3 to 4 inches long, have abundant stomata, but as yet only a single very slender bast-bundle, median on the upper surface.

---

* It is therefore proper to examine among the roots for spores whenever none can be found on the plant; one or the other may be discovered there and help out the diagnosis which otherwise may rest in obscurity.

The species of *Isoëtes*, perhaps 40 to 60 in number (according to the views taken of the different forms, whether species or varieties), are distributed over the whole globe, apparently more abundant in the temperate than in the tropical zones. In North America we have 13 species, with 12 varieties, to which I add one from Cuba; from Mexico we have received as yet none. More are expected to be found when the attention of collectors is more earnestly directed to them.

Most of the species may be called water-plants, growing in stagnant or in slow-running water; a few are always submerged and are found out of water only in abnormal conditions, e.g. in unusually dry seasons. The majority are of amphibious growth, entirely or partially submerged dnring the wet seasons, in winter and especially in early spring; but at the growing season they partially get out of the water, leaving only their trunk and lower part of the leaves immersed. These species do not come to perfection when completely immersed, though they may not be entirely infertile; it seems that partial exposure to the atmosphere is necessary to their well-being. A variety of the amphibious species are the tidal ones, which are alternately emerged and submerged during the changes of the tides; they are found in the estuaries of some of our Atlantic rivers. Then we have a few species which we are justified in calling terrestrial, as we find them, when fully developed, on dry land; but it seems that for their germination and their growth in early spring they also require moisture and water; we therefore find them on low or flat grounds which may be overflowed in spring, or in springy localities, but they fully develope and become fertile only when out of water. *I. melanopoda*, which belongs to this class, normally matures in June or early in July, and its leaves wither before the end of that month; by keeping it immersed, however, I have kept it fresh and growing throughout the summer, but under these conditions it remained perfectly sterile. Those terrestrial species which grow on arid hills around the Mediterranean must require even less moisture, and are probably satisfied with temporary drenchings.

The submerged and the amphibious species are generally found, some in soft mud, others between gravel and stones; the amphibious ones generally in deep mud. Our terrestrial species grow mostly in heavy, retentive soil.

§ 4. *Systematic Arrangement.*

Our 14 species can be classed—

1. According to the developement of the trunk; thus we have 13 species, all our North American ones, with a *bilobed*, and only the single Cuban one with a *trilobed trunk*.

2. According to their mode of growth:

a. Submerged species, which normally always grow under water: *I. lacustris*, *I. pygmæa*, *I. Tuckermani*, *I. echinospora*, and *I. Bolanderi*.

b. Amphibious species, which grow in water but have their leaves usually emerged : *I. saccharata*, *I. riparia*, *I. flaccida*, *I. Engelmanni*, *I. melanospora*, and probably *I. Cubana*.

c. Terrestrial species, which grow during the greater part of their life on dry (or moist) land : *I. melanopoda*, *I. Butleri*, and *I. Nuttallii*.

These divisions seemed to be the most natural ones so long as but few species were known, and when other characters, such as the presence or absence of stomata, seemed to correspond with and to confirm them ; but, since we know more species and more about them, we have learned that structural and biological characters do not always go together ; and, moreover, that some species are in some forms submerged and in others almost amphibious (*I. echinospora*), and that some amphibious ones become sometimes almost terrestrial (*I. Engelmanni*). A less important objection is, that the biological characters cannot be made out in herbarium specimens.

3. According to the condition of the velum :

a. A partial or narrow velum has *I. lacustris*, *I. pygmæa*, *I. Tuckermani*, *I. echinospora*, *I. saccharata*, *I. Bolanderi*, *I. riparia*, *I. Engelmanni*, *I. Howellii*, *I. melanopoda*, and *I. Cubana*. In *I. Butleri* the velum is almost completely absent.

b. A complete velum has *I. melanopoda*, *I. flaccida*, and *I. Nuttallii*.

The anatomical structure of the leaves, viz., the presence or absence of stomata and of peripheral bast-bundles, furnishes us valuable characters, and, though somewhat difficult to ascertain and therefore less practical, may after all have to be placed in the first line, as it seems to correspond best with the essential characters of the plant.

4. According to the presence or absence of stomata in the leaves :

a. Without any stomata are only *I. lacustris*, *I. pygmæa*, and *I. Tuckermani*. The typical European *I. echinospora* also belongs here, but the different American forms of this species must be classed among the next, though some of them have only very few stomata, often difficult to make out.

b. With stomata (generally abundant) : *I. echinospora* (American varieties), *I. saccharata*, *I. Bolanderi*, *I. riparia*, *I. melanospora*, *I. Engelmanni*, *I. Howellii*, *I. flaccida*, *I. melanopoda*, *I. Butleri*, *I. Nuttallii*, and *I. Cubana*.

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

5. According to the presence or absence of peripheral bast-bundles:

a. Without bast-bundles: *I. lacustris*, *I. pygmæa*, *I. Tuckermani*, *I. echinospora*, *I. saccharata*, *I. Bolanderi*, *I. riparia*, and *I. melanospora.*

b. With bast-bundles: *I. Engelmanni*, *I. Howelli*, *I. flaccida*, *I. melanopoda*, *I. Butleri*, *I. Nuttallii*, and *I. Cubana.*

The comparative size or the sculpture of the spores, and the number and length of the leaves, furnish no legitimate grounds for classification; still it may be mentioned here, that the largest macrospores (0.45 to 0.80 mill. in diam.) are found in *I. lacustris*, *I. Butleri*, and *I. riparia;* the smallest (0.25 to 0.45 mill.) in *I. melanopoda*, *I. flaccida*, and *I. Engelmanni* var. *valida.*

The largest number of leaves, 50 to 200, are observed in the last mentioned form, in *I. melanopoda* and in *I. Nuttallii;* the smallest number, 5 to 20, in *I. pygmæa*, *I. melanospora*, *I. saccharata*, and *I. Bolanderi.*

The longest leaves (15 to 25 inches long) we meet with in *I. Engelmanni*, *I. flaccida*, and *I. Cubana;* the shortest (½ to 3 inches long) in *I. pygmæa*, *I. melanospora*, and *I. saccharata.*

The following classification of our species is proposed as the best I can find, though by no means a faultless one.

I. **Trunk bilobed.**

A. Submerged species with quadrangular leaves, without, or in 4 and 5 with few or many stomata and without peripheral bast-bundles; velum incomplete.

1. *I. lacustris.* 2. *I. pygmæa.* 3. *I. Tuckermani.* 4. *I. echinospora.* 5. *I. Bolanderi.*

B. Amphibious species with abundant stomata in the quadrangular leaves.

* Without peripheral bast-bundles (these are intermediate between the submerged and the truly amphibious species.)

† Velum partial.

6. *I. saccharata.* 7. *I. riparia.*

† † Velum complete.

8. *I. melanospora.*

* * With peripheral bast-bundles.

† Velum partial.

9. *I. Engelmanni.* 10. *I. Howelli.*

† † Velum complete.

11. *I. flaccida.*

C. Terrestrial species, maturing when entirely out of water, with abundant stomata and peripheral bast-bundles in the nearly triangular leaves.

* Velum partial or almost wanting.

12. *I. melanopoda.* 13. *I. Butleri.*

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

* * Velum complete.

14. *I. Nuttallii.*

II. **Trunk trilobed,** numerous stomata and bast-bundles in the quadrangular leaves; velum partial.

15. *I. Cubana.*

§ 5. *Geographical Distribution.*

Only a small part of the North American continent has been well explored for Isoëtes, and there, from Massachusetts to the Chesapeake Bay, they appear abundant enough; farther south, and in the whole interior and western part of the continent, they have thus far been found only in a few localities. Some species are quite local, as is the case also with many species of the old world, while others are widely distributed. Our two northern species are identical with, or closely allied to, European forms, all the others are quite distinct from such, so that there is scarcely more than a generic analogy between the species of our middle and southern regions with the Mediterranean ones or those of other regions of the globe.

The old Linnean *Isoëtes lacustris* is the only species which has been found to extend from the Atlantic to the Pacific States, and it probably occupies a northern belt of the northern hemisphere, though it seems not to have been discovered as yet in Asia. The American forms allied to *I. echinospora*, the other North European species, are the most common in the belt of northern States as far west as Michigan, and have been detected also on the western slope of the Rocky Mountains. Of the others, *I. Engelmanni* extends from Massachusetts to Georgia and westward to Missouri, though thus far not found anywhere else west of the Alleghany Mountains. *I. flaccida* is peculiar to Florida and *I. Bolanderi* to the lakes of the western mountain chains, the Rocky Mountains as well as the Sierra Nevada. *I. melanopoda* occupies parts of the Mississippi valley from Central Illinois to Northeastern Texas, while *I. Nuttallii* is the only species found in the valley of the Columbia river. All the other species seem to be nearly or quite local, *I. pygmæa*, in the Californian Sierra, but most of them on the Atlantic border; thus *I. Tuckermani* occurs only near Boston, *I. saccharata* on streams emptying into the Chesapeake Bay, and *I. melanospora* only on that peculiar and, botanically, so interesting rock, the Stone Mountain of Georgia. Some species which seemed local have lately assumed a little wider range, though yet quite restricted; among these I mention *I. riparia* of the banks of the lower Delaware river, which occurs also farther north, and *T. Butleri*, first known only from the Indian Territory, now also found in Tennessee. There can be no doubt but that some of the apparently local species will yet be found in a more extended area, when botanists will include in their researches these obscure and inconspicuous plants.

From the warmer parts of North America we know only *I. Cubana*, from Cuba; none have yet turned up from Mexico.

The following table will explain itself.

	Total species and varieties.	I. lacustris.	pauperecula.	I. pygmæa.	I. Tuckermani.	I. echin. Braunii.	robusta.	Boottii.	muricata.	I. Bolanderi.	I. saccharata.	I. riparia.	I. melanospora.	I. Engelmanni.	gracilis.	valida.	Georgiana.	I. Howellii.	I. flaccida.	I. melanopoda.	pallida.	I. Butleri.	immaculata.	I. Nuttallii.	I. Cubana.
Greenland	1	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Nova Scotia	1	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Maine	2	....	....	....	....	1	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....
New Hampshire	2	1	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Vermont	4	....	....	....	....	1	1	....	....	....	....	1	....	....	1	....	....	....	....	....	....	....	....	....	....
Massachusetts	8	1	....	....	1	1	....	1	1	....	....	1	....	1	1	....	....	....	....	....	....	....	....	....	....
Rhode Island	2	....	....	....	....	....	....	....	....	....	....	....	....	1	1	....	....	....	....	....	....	....	....	....	....
Connecticut	1	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....
New York	3	1	....	....	....	1	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....
Ontario	2	....	....	....	....	1	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....
Michigan	2	1	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Pennsylvania	4	....	....	....	....	1	....	....	....	....	....	1	....	1	....	1	....	....	....	....	....	....	....	....	....
New Jersey	4	....	....	....	....	1	....	....	....	....	....	1	....	1	1	....	....	....	....	....	....	....	....	....	....
Delaware	3	....	....	....	....	....	....	....	....	....	....	1	....	1	....	1	....	....	....	....	....	....	....	....	....
Maryland	1	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Virginia	1	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....
Georgia	2	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	1	....	....	....	....	....	....	....	....
Florida	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....
Tennessee	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....
Illinois	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....
Iowa	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....
Missouri	1	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....
Indian Territory	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1	....	....	....
Texas	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....
Colorado	1	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Utah	2	....	....	....	....	1	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Wyoming	1	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Idaho	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....
Washington Territory	2	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....
Oregon	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1	....
California	3	....	1	1	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Cuba	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1

8 species and varieties have been found in Massachusetts.
4 " " " " Pennsylvania and New Jersey.
3 " " " " New York and California.
2 " " " " 10 States, Territories, or Provinces.
1 " " " " 15 " " " "

§ 6. *Enumeration of the Species.*

I. Trunk bilobed.

A. Submerged, normally growing under water, only in unusually dry seasons coming above the surface; leaves quadrangular, without peripheral bast-bundles; velum incomplete.

* Without stomata.

1. I. LACUSTRIS, Lin. Leaves stout, rather rigid, obtusely quadrangular, acute but scarcely tapering, dark or olive-green, 10 to 25 in number, 2 to 6 inches long; sporangium orbicular to broadly elliptical, not spotted, with a rather narrow velum; ligula triangular, short or somewhat elongated; macrospores 0.50 to 0.80 mm.* in diameter, marked all over with distinct or somewhat confluent crests; microspores smooth, 0.035 to 0.046 mm. in the longer diameter.— Syst. Veg. I. 1753; Durieu Bull. Bot. Soc. France, 8, p. 164, 1861; Gray Man. ed. 5, p. 675.

Var. PAUPERCULA with fewer (10 to 18), thinner, shorter (2 to 3 inches) leaves and smaller spores (macrospores 0.50 to 0.66 mm. diam.; microspores somewhat granulated, 0.026 to 0.036 mm. long).

A northern species of Europe and America, generally gregarious on gravelly soil in the bottom of lakes under 1 to 4 or 5 feet of water, farther south only on mountains; maturing in Sept. and Oct. Catskill Mountains, N. Y. *Schweinitz*, Echo Lake, Franconia Mountains, N. H. *Tuckermann*, *Engelmann;* in Massachusetts, in Fresh Pond near Cambridge, *W. Boott* and Uxbridge, *J. W. Robbins;* Brattleborough, Vt., *C. C. Frost;* Saulte de Ste. Marie on Lake Superior, *Porter and Leidy*. The variety in Grand Lake, Middle Park, Colorado, over 8,000 ft. alt., *Engelmann,* and in Castle Lake near Mt. Shasta, California, 7,000 ft. alt., *C. G. Pringle.* — This is the original Linnean species, formerly confounded with others, and first clearly established by Durieu, l. c. It is always readily recognized by its rigid, rather thick, not gradually tapering dark green leaves, which do not collapse when taken out of the water, and by the size and sculpture of the spores. The variety *paupercula* is based on western mountain specimens, and is characterized by the smaller proportions of all parts, and especially of the (for the species) unusually small microspores. Durieu, l. c. 11, p. 101, distinguished a form with exceptionally large macrospores (0.70 to 0.80 mm. diam.) as *I. macrospora* from a single specimen from the Herb. Acad. N. S. Philad., with the label "Catskill Mountains" in the handwriting of Schweinitz; but others show sometimes spores of similar dimensions, e.g. specimens from Lake Superior; and such have also been found in Europe, though there the spores rarely reach a size of over 0.65 to 0.70 mm.

2. I. PYGMÆA, Engelm. One of the smallest species with a few (5 to 10) short (½ to 1 inch long) stout, rigid, bright green leaves, abruptly

---

* I adopt for the smaller measurements the metrical system, which will gradually but surely supersede the old and clumsy method, while in the larger measurements, as the length of leaves, I still adhere to the foot and inch as the one yet best understood. The millimeter is, as is well known, equal to very nearly half a line.

tapering to a fine point, with very short, often almost square, epidermis cells; orbicular sporangium not spotted, with a narrow velum; macrospores 0.36 to 0.50 mm. thick, marked with minute, rather regular, distinct or rarely confluent warts; microspores 0.024 to 0.029 mm. long, almost smooth and brown.—Am. Naturalist, 8, 214.

Found only once, deeply immersed in a cold alpine stream on the eastern slope of the Mono Pass, California, 7,000 ft. alt., *H. Bolander.*—This curious diminutive species is a close ally to the last by the structure of the leaves and the mode of living, but is widely separated from it by the sculpture of the spores; the shortness of the epidermis cells is quite peculiar to it, and so are the close transverse partitions; the walls of the leaf and the dissepiments are thinner than in the last, consisting of only a few layers of cells. The minute tubercles of the macrospores are most distinct on the lower surface, but become sometimes confluent on the upper side.

3. I. TUCKERMANI, A. Braun in litt. A small plant with very slender tapering olive-green leaves (10 to 30 in number, mostly 2 to 3 inches long), the outer recurved, walls and partitions rather thick for the diameter of the leaf; sporangium mostly oblong, white or rarely brown-spotted, the upper third covered by the velum; macrospores 0.44 to 0.56 mm. diam., the upper segments marked with prominent, somewhat parallel and branching ridges, the lower half reticulated; microspores smooth or nearly so, 0.026 to 0.032 mm. long.—Engelm. in Gray Man. l. c. 676.

In several ponds and streams near Boston, maturing from August to October; first discovered by *E. Tuckermann*, 1848, in the Mystic river very near where it issues from the pond; in the same locality and in Mystic, Spy and Horn ponds, *W. Boott*, "always immersed in fresh water, sometimes only a few inches below the surface, often in places which are subject to a tide of almost two feet in height, generally gregarious and carpeting the bottom with an olive-green turf." The leaves are usually not longer than two or three inches, and, at least the outer ones, recurved; occasionally, in slender specimens, probably from deep water I have seen them straighter and over 5 inches long. The sculpture of the spores is very characteristic, wavy, somewhat branching ridges run from the three upper commissures in right angles; on the lower surface they interlace, covering it with an irregular network. Some specimens collected by Mr. Boott at the end of October seem to indicate a second growth, as within the circle of microspore-bearing leaves, and after the outer ones with their macrosporangia had fallen, an inner growth bearing macrosporangia was noticed. One of his specimens is of particular morphological interest, as it shows four heads or leaf-buds from the same healthy and vigorous trunk, three close together on top and a fourth on the side, separated from the others by a deep incision in the trunk. This division of the axis did not result from any proliferation of the leaves, but most probably from a lesion of the centre of vegetation, and is of very rare occurrence in this genus, where the simplicity of the axis is so particularly marked (see above p. 358).

4. I. ECHINOSPORA, Durieu. One of the smaller species with 10 to 30 or 40 soft bright green or sometimes reddish leaves, gradually and regularly tapering from a thick base to a very slender elongated point absolutely without stomata, 2 to 4 or sometimes 5 inches long; sporangia orbicular to broadly oval, unspotted, with a narrow velum; macrospores 0.40 to 0.50 mm. thick, densely covered with delicate, erect, truncate, or slightly forked spinules; microspores 0.030 to 0.034 mm. long, almost smooth.—Bull. Bot. Soc. Fr. 8, 164.

Only in Europe from Northern Italy to Germany, France and England, extending to Lapland and Iceland, but apparently not in America.

In this country we have a series of forms which have been distinguished by eminent anthority, especially on account of the presence of stomata so various in number and often so difficult to discover, and of a slight difference in the form and size of the microscopic spinules which cover the macrospores. I have thought best to unite them specifically with the European type, though it seems strange that in the European plant stomata should be absolutely absent, and it must remain subject to individual judgment, if not doubt, which view ought to be preferred. Nearest to the European true *I. echinospora* stands the var. *Braunii* and the other extreme is var. *muricata*, wide-ranging forms of a single type. The same difficulties, the same doubts, and the same solution, we find in studying some foreign forms and especially those allied to *I. velata* of the south of Europe.

* * Stomata few.

I. ECHINOSPORA, var. BRAUNII, Engelm. Rather small, with 13 to 15 green or reddish-green erect or spreading, rather short (3 to 6 inches long), tapering, soft leaves, generally with few stomata towards the tip only; sporangia orbicular to broadly elliptical, spotted, generally ½ or even ¾ covered by a broad velum; macrospores 0.40 to 0.50 mm. thick, rarely a little longer, covered with broad, retuse spinules, sometimes somewhat confluent, and then dentate or incised at tip; microspores 0.026 to 0.030 mm. long, smooth.—Gray Man. l. c. *I. Braunii*, Durieu l. c. 11, p. 101.

The most common species of our flora from New Jersey and Pennsylvania, northward and northwestward, sometimes on gravelly soil, at other places reported from soft mud, in ponds or slow-running streams, also near the banks of larger lakes or under the influence of tidewater, normally submerged from a few inches to several feet, in dry seasons sometimes getting out of water; associated with *Eriocaulon septangulare*, *Lobelia Dortmana*, *Sparganium*, *Scirpus*, *Eleocharis*, etc. New Jersey: in tidewater of Tom's river, a slender long-leaved form, *C. F. Parker*, *C. E. Smith*, and others; in a lake in Morris Co., *T. C. Porter*. Pennsylvania: Montrose, Susquehanna Co., *A. P. Garber;* Great Lake, Pocono Mountain, *Porter & Canby;* Presque Isle, Erie, *A. P. Garber*. New York: Catskill Mountains in the lake near the hotel, *G. W. Clinton;* Round Lake above Bolton, west of Lake George, on white sand, and in Lake Placide, *L. Lesquereux;* Luzerne Lake and in Niagara river below Buffalo, *G. W.*

Clinton; at the head of Goat Island, Niagara, between stones, *G. Engelmann;* Oneida Lake, *J. A. Paine;* in Oswego river, *F. Pursh*, probably (see p. 353). Massachusetts: Mystic Pond near its lower end, gregarious in soft mud in 1 foot of water, also in other parts of the same pond, and in Spot, Spy and Horn ponds, on sandy bottom, all near Boston, *W. Boott;* Hammond's Pond, *W. G. Farlow;* Concord brook, gregarious, on firm bottom, *H. Mann;* Beaver Pond near Beverly, *J. L. Russell;* Uxbridge, in Grafton Pond and several other ponds, *I. W. Robbins.* Vermont: Mt. Mansfield, in the Lake of the Clouds, *C. G. Pringle*, *H. Mann*, on gravelly bottoms, 1 to 2 feet deep; Lake Dunmore, *A. W. Chapman.* New Hampshire: Lake Winnipiseogee, in mud with *Gratiola aurea*, *Eriocaulon*, etc., *G. Engelmann* (these specimens were the types of Durieu's *I. Braunii*), *H. Mann*, *W. Boott;* Echo Lake in the Franconia Mountains (where Mr. Tuckerman and myself had found *I. lacustris*), *W. Boott.* Maine: Moose Lake on Kennebunk river, *C. E. Smith.* Nova Scotia, Shelburne, *T. P. James.* Greenland, in the south, "Tessermint," *I. Vahl* (perhaps this is the true *I. echinospora;* I could not well analyze the small and poor specimen in my possession). Westward the species has been found in Western Canada (Ontario) near Hastings and in a lake northeast of Belleville, on a muddy bottom, *J. Macoun.* Michigan: Bellisle in Detroit river, *H. Gillman.* Utah: Lake at the head of Bear river in the Uintah Mountains, at 9,500 feet alt., *S. Watson;* this is the most western and highest, quite isolated, locality known to me.

This form is most closely connected with the European type; the leaves are perhaps not quite so finely tapering; stomata can always be found, at least near the tip of the leaf; the sporangia, white in the type, are spotted with brown sclerenchym cells; the macrospores I cannot distinguish either in size or sculpture; the microspores I find a little smaller. I may state here that the name of *I. Braunii* is preoccupied, as it has already been given to one of the two species of the Tertiary deposits, the well marked spores of which have been discovered in the German Brown Coal strata; Prof. Braun therefore proposed for our plant, if it should eventually be considered distinct, the name of *I. ambigua.*

Var. ROBUSTA, Engelm., similar to the last, but much stouter, with 25 to 70 leaves, 5 to 8 inches long, with abundant stomata all over their surface; velum covering about one-half of the large, spotted sporangium; macrospores 0.36 to 0.55 mm. thick, with the sculpture of the last; microspores the same as in last.

In Lake Champlain, on the north end of Isle La Motte, on a firm sandy soil with silt, in 1 to 2 feet of water, *C. G. Pringle.* Larger and stouter than any form of the last, but principally distinguished from it by the abundance of stomata.

Var. BOOTTII, Engelm. l. c. Leaves erect, soft, bright green, fewer (12 to 20) short (4 to 5 inches long); stomata, mostly few, near the tip; sporangia nearly orbicular, pale-spotted, $\frac{2}{3}$ or more covered by the broad velum; macrospores 0.39 to 0.50 mm. thick, with longer and slenderer

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

delicate, generally simple spinules; microspores 0.026 to 0.030 mm. long. —*I. Boottii*, A. Braun in litt.

Near Boston, in the Round Pond, Woburn, 2 to 3 feet under water, and in the brook of Tofit Swamp, Lexington, sometimes out of water, *Wm. Boott.* Very striking on account of the delicate green color of its soft leaves, and the long and slender spinules of the spores.

Var. MURICATA, Engelm. l. c. Leaves (15 to 20) long (6 to 12 inches), flaccid, bright green, with very few stomata; sporangium broadly oval, pale-spotted, about half covered by the velum; macrospores a little larger (0.40 to 0.58 mm. thick), with shorter and more confluent, therefore sometimes almost crest-like spinules: macrospores slightly rough on the edges, 0.028 to 0.032 mm. long.—*I. muricata*, Durieu l. c.

In the shallow and more rapid parts of Woburn creek, and in Abajona river, the main source of Mystic Pond, near Boston, scattered over a clean gravelly bottom and always submerged, *W. Boott.* Remarkable for its long flaccid leaves and the shorter spinules of the macrospores, which form sometimes crests so that Durieu could compare it with *I. riparia.*

5. I. BOLANDERI, Engelm. One of the smaller species with erect, soft, bright green leaves tapering to a fine point, 5 to 20 or 25 in number, 2 to 4½ inches long, with thin walls and partitions, and generally not many stomata; sporagium broadly oblong, mostly without any spots, with a narrow velum; ligula triangular; macrospores 0.30 to 0.40 or rarely 0.45 mm. thick, marked with minute low tubercles or warts, rarely confluent to wrinkles; microspores 0.026 to 0.031 mm. long, generally spinulose; rarely, in the Rocky Mountain form, smooth, deep brown.—Am. Naturalist, 8, 214.—*I. Californica* Engelm., name only in Gray Man. l. c.

A western mountain species, found gregarious in ponds and shallow lakes of the Sierra Nevada of California, northward to the Cascades and eastward to the Rocky Mountains: in little pools on meadows in the upper Tuolumne valley 9,000 to 10,000 feet alt., on Mt. Dana, on the Mono trail, in Mary's Lake near the summit, 7,000 feet alt., in small lakes about Cisco 4 500 to 5,000 feet alt, "mostly gregarious in mud covering gravel, in 1 or 2 feet of water," *H. Bolander;* Ice Lake, near Soda Spring station, 7,500 feet alt., with *Menyanthes trifoliata*, *Engelmann;* in many lakes of the high sierras, reported by A. Kellogg; on Mt. Adams, Washington Terr., *W. N. Suksdorf,* in the soft muddy bottom of a shallow pond near the falls of the Yellowstone river in Wyoming, nearly covering the muddy bottom, partly emerged near the banks, *C. C. Parry;* in a subalpine lake at Alta, Wasatch Mountains, Utah, *M E. Jones*, and in a lake in the Gunnison region, Western Colorado, covering ten acres of ground with *Menyanthes*, *T. S. Brandegee.*—This species has much the appearance of *I. echinospora* var. *Bootti*, with its soft bright green leaves; the stomata are often difficult to make out.

B. Amphibious, partially emerged, submergedonly in the earlier period of their growth or temporarily; stomata always present.

* Without peripheral bast-bundles; intermediate between the submerged and the truly amphibious species.

† Velum partial.

6. I. SACCHARATA, Engelm. A small plant, usually with a flat, depressed trunk; leaves subulate, olive-green, spreading, 10 to 20 in number, 2 to 3 inches long; sporangium oblong, spotted, with a narrow velum; ligula triangular; macrospores 0.40 to 0.47 mm. thick, covered with very minute distinct or sometimes a little confluent warts; microspores papillose, 0.024 to 0.028 mm. long.—Gray Man. l. c.

On the banks of the Wicomico, below Salisbury, and of the Nanticoke rivers which empty into the Chesapeake Bay, eastern shore of Maryland, above salt water, scattered on a thin stratum of mud covering a bed of gravel, overflowed by the tides, in company with *Sagittaria pusilla*, *Eriocaulon*, *Tillaca simplex*, *Micranthemum Nuttallii*, etc., *W. M. Canby*. The trunk is in this species unusually flat, about half as thick as it is wide in the direction of the groove; about one inch of the base of the leaves is pale, and covered with mud agitated by the tides, the upper part is olive-green and when out of water apt to be borne down by mud; stomata abundant; macrospores as if sprinkled over with minute white grains of sugar, whence the name.

7. I. RIPARIA, Engelm. A larger plant with slender but rather rigid deep green leaves (about 15 to 30 in number), 4 to 8 inches long, rarely longer; stomata numerous, dissepiments thick, consisting of about 4 layers of cells; sporangia mostly oblong, distinctly spotted by groups of brown sclerenchym cells, ¼ or rarely ⅓ of it covered by the velum; macrospores among the largest, 0 45 to 0.65 mm. in diam., marked with jagged crests isolated, or anastomosizing, especially on the lower surface, which thus becomes somewhat reticulated; microspores more or less tuberculated, 0.028 to 0.032 mm. long.—Flora, Regensb. Mar. 31, 1846; Am. Jour. Arts & Sci. 3, p. 52, 1847: Gray Man. l. c.

On the banks of the lower Delaware river between the limits of the tides in mud covering gravel, from Burlington, *T. A. Conrad*, to Wilmington, *W. M. Canby*, and especially about Philadelphia, where *Nuttall* first discovered and *W. S. Zantzinger*, *E. Durand* and the later botanists have abundantly collected it, associated with *Elatine*, *Limosella*, *Micranthemum*, *Sagittaria pusilla*, etc.; also in millponds and still parts of streams in New England, Uxbridge, *J. W. Robbins*, Brattleborough, *C. C. Frost*, and northward, maturing in August and September. — Near *I. lacustris*, with leaves as dark green and almost as rigid, and with spores approaching it in size and sculpture, but readily distinguished by its stomata and by the spots on the sporangium; from *I. echinospora* var. *Braunii*, with which smaller forms it may possibly be confounded; it can always be known by the darker, stiffer leaves and especially by the character of the spores. Some of the Uxbridge specimens, entirely submerged 2 to 4 feet

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

deep in water, have slenderer and longer (even 12 inches) leaves. The trunk, mostly thick, I have once found 3-lobed. Germinating spores and young plantlets were found in June by Mr. Durand indicating germination in spring and early summer.

Farther northward, in Maine, *J. W. Chickering*, and in Canada West, Crow river, Hastings Co., *J. Macoun* (here in running water with *Brasenia* and *Potamogeton*), a form occurs with very few stomata on leaves and apparently two weak bast-bundles, an upper and a lower one, very pale spots on the sporangia and smoothish microspores, which might be designated as var. *Canadensis*, but too little is known about it as yet to form a definite opinion.

† † Velum complete.

8. I. MELANOSPORA, Engelm. One of the smallest species, with a flat, only slightly bilobed trunk; leaves few (5 to 10, 2 to 2½ inches long), distichous, slender, tapering, light green, spreading; sporangium orbicular or almost obcordate, ½ to 1 line long, entirely covered by the velum, unspotted; ligula short-triangular, obtuse, or about semi-orbicular; macrospores 0.35 to 0.45 mm. in diameter, roughened with distinct or rarely somewhat confluent warts, dark colored; microspores 0 028 to 0.031 mm. long, smoothish or slightly papillose.—Transact. St. Louis Acad. Sci. 3, p. 395, note.

Stone Mountain near Atlanta, Georgia, covering the bottom of shallow excavations on the naked granite surface, a few inches deep and a few feet in diameter, holding about one inch of light, black soil and at best a couple of inches of water supplied only by rains and dews, and completely dried up and baked for weeks or months under the action of the glaring southern sun on the bare rock, when only the little shrivelled trunks with their black withered matted roots remain, to revive under a fresh supply of autumnal rains; with *Amphianthus pusillus*, discovered by *W. M. Canby*, observed since by *A. Gray* and myself; maturing in May and June. A cake of them taken home with me began to sprout soon after being moistened, and, vegetating in the room through winter, fully developed in early summer, and afforded a fine opportunity for studying this curious little species, interesting on account of its native locality, its endurance of drought, its mode of growth and the phyllotactic arrangement of its leaves, its entire velum and its dark spores; it seemed to thrive best when only the base of the leaves was covered with water. The trunk is unusually flat and only slightly grooved underneath and on one side, only about ½ to 1 line thick and 2 to 4 lines in the longer and not much more than half as much in the shorter diameter; distichous leaves soft and slender, their dissepiments consisting of only two layers of cells. The sporangia, ½ to ¾ line wide, readily separate from the leaf-bases, so that they are sometimes found adhering to the trunk after the leaf itself has already fallen away. The macrospores, only 8 to 20 in each sporangium, are black when moist

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

and dark gray when dry; in some I find the warts much smaller than in others, but never wanting; microspores also quite dark brown.

* * With peripheral bast-bundles.

† Velum partial.

9. I. ENGELMANNI, A. Braun. Our largest species with numerous (25 to 100) long (9 to 20 inches or more) light green leaves with abundant stomata; sporangium usually oblong to linear-oblong, unspotted; velum narrow; ligula elongated from a triangular base; macrospores 0.40 to 0.52 mm. thick, delicately honeycomb-reticulated; microspores 0.024 to 0.028 mm. long, generally smooth.—Flora l. c.; Am. Jour. l. c.; Gray Man. l. c.

Var. GRACILIS, Engelm. Often submerged, with fewer (8 to 12) leaves, 9 to 12 inches long; the bast-bundles sometimes quite small, or only two of them.—Gray Man. l. c.

Var. VALIDA, Engelm. The stoutest of all our species; leaves 50 to 100 or even 200, 18 to 25 inches long, keeled on the upper side; sporan. gium often linear-oblong (4 to 9 lines long), ⅓ or often ½ or even ⅔ covered by the broad velum; macrospores rather smaller, 0.32 to 0.48 mm. thick; microspores 0.024 to 0.027 mm. long, spinulose,—Gray Man. l. c.

Var. GEORGIANA. Similar to the type; leaves few (in the only specimens seen 15, 10 to 12 inches long), rather slender; oval sporangium with narrow velum; macrospores larger, 0.48 to 0.56 mm. thick; microspores 0.028 to 0.031 mm. long, smooth.

In ponds and ditches, immersed in mud, rarely found in slow-running streams, in company with the ordinary vegetation of such localities, *Bidens*, *Polygonum*, *Lycopus*, *Carices*, *Leersia*, etc.; mature in summer; probably throughout the middle States, but thus far only found — from Massachusetts: Arlington brook, Alewife brook, West Cambridge brook, Woburn, *Wm. Boott*. Rhode Island: Newport, *W. G. Farlow*. Connecticut: Meriden, *F. W. Hall* — to New York: Peekskill, *W. H. Leggett*. New Jersey: *E. Durand*, *C. F. Austin*, and others. Pennsylvania, Bethlehem, *C. J. Moser*, *E. Durand*, *S. Wolle;* Delaware Water-Gap, *S. W. Knipe;* Darby, *J. G. Hunt;* Philadelphia, *E. Durand*, *C. E. Smith*, and others. Delaware: *Wm. M. Canby*, *A. Commons*. Virginia: Salt Pond Mountain, with *Parnassia asarifolia*, *W. M. Canby*. Missouri: St. Louis, *N. Riehl* and *G. Engelmann*, 1842, in a single locality, where it was soon afterwards destroyed by cultivation: not found otherwise west of the Alleghany Mountains. Var. *gracilis* seems to be a northern form: Brattleborough, in Clark's Pond, *C. C. Frost;* Colebrook's, in a shallow stream with gravelly bottom, *J. W. Robbins;* New Haven, in fresh water on a tidal shore, *D. C. Eaton;* Newport, *Bridges*, *G. Thurber;* Passaic river, near low-water mark, *J. Ennis*. Var. *valida* was discovered in Pennsylvania near Warrior's Mark, Huntington Co., and Smithville, Lancaster Co., *T. C. Porter;* and in Delaware, Wilmington, *W. M. Canby*. Var. *Georgiana* comes from a mountain stream, Georgia, the Horseleg creek,

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

a tributary of Coosa river, Floyd Co., in slow-flowing water about a foot deep, *A. W. Chapman.*

The trunk of this species is larger than I have seen it in any other, and more variable in form; sometimes it is quite flat and over one inch wide, especially in var. *valida*, or it is thick; and I have seen it even twice as high as it was wide, 4½ lines wide in the largest transverse diameter and 7 lines high; this, however, is a very unusual form. The plant is submerged in spring with the leaves partly floating; later, when the water recedes, the older leaves are spread out on the mud, but the later growth becomes erect; var. *gracilis* is often more or less submerged, and its weakly developement is probably owing to this circumstance, while var. *valida* is the stoutest form we have, and one of the stoutest in the whole genus, perhaps only *I. Malinveriana* of the rice fields of Lombardy surpassing it. A very small form, only 5 inches high, has been collected in a springy place on a rocky hillside near Wilmington, Del., by A. Commons, otherwise not distinct. The Georgia variety, characterized by its larger spores, ought to be further studied. In my Missouri specimens I find, among many of the ordinary type with white sporangium, a few where this organ is uniformly brown, not spotted. The dissepiments of the leaves consist, the median of 3 to 4 and the transverse one of 2 to 3 layers of cells. The well marked reticulation of the macrospores is formed of very thin fragile laminæ, not of thick ridges as in some other species.

10. I. Howellii, Engelm. n. sp. Middle sized, leaves (10 to 25) bright green (5 to 8 inches long) with thick dissepiments; sporangium oval (1½ to 2½ lines long), unspotted, ¼ to ½ covered by the velum; subulate ligula as long as sporangium; macrospores 0.43 to 0.48 mm. in diam., rough, with prominent rounded single or sometimes confluent tubercles.

On border of ponds at the Dalles of the Columbia, Oregon, *J. & T. J. Howell*, 1880, not quite mature in June. — I insert this species which has just been communicated to me through the kindness of Mr. G. E. Davenport, while the manuscript is in the hands of the printer; this must excuse some discrepancies in the foregoing pages, where no reference could be made to it. The new species is distinguished from the similar *I. Bolanderi* by the longer leaves, larger more prominently marked macrospores, and especially by the distinct peripheral bast-bundles, which place it near the foregoing one, by the thick dissepiment consisting of 4 to 6 layers of cells, and by the unusually narrow and long ligula; the tubercles of the spores are quite prominent, as high as they are wide, rounded at top; microspores light brown, smooth. — Among the specimens of this species, and probably collected with it, I find a single one similar in the structure of the leaf, but without a trace of a velum, the sporangium being entirely naked and only attached by the median line to the leaf base; it is unfortunately immature, and can only be indicated as a probably new species, *I. nuda*. This would not be the first instance of two species growing together in the same pond or lake; in Mystic Pond we find *I. Tuckermani*

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

and *I. echinospora* var. *Braunii*, in Echo Lake the latter and *I. lacustris*, and in Europe not rarely this together with *I. echinospora*.

† † Velum complete.

11. I. FLACCIDA, Shuttleworth, in sched. A slender plant of light green color; leaves often very long, 10 to 35 in number, 15 to 24 inches long, sometimes entirely submerged, or partly floating on the surface, or entirely emerged; sporangia oval, 2 to 3 lines long, entirely covered by the velum; macrospores 0.30 to 0.42 mm. in diam., covered with many or rarely few comparatively large flattish tubercles, distinct or confluent into labyrinthiform wrinkles; microspores not seen. — A. Braun in Flora l. c.; Amer. Jour. l. c.; Chapm. Fl. So. States, p. 602.

Var. RIGIDA, a smaller form with still more slender, erect, dark green leaves (about 10 to 15 in number, 5 to 6 inches long).

Var. CHAPMANI larger, light green, leaves floating (about 30, 18 inches long); sporangium orbicular; spores larger, macrospores 0.44 to 0.55 mm. in diam., marked as the type, or, especially on the upper side, almost smooth; microspores 0.027 to 0.030 mm. long, slightly papillose.

Florida, on the muddy bottom of lakes or swamps, first found by Dr. Rugel in Lake Immonia, north of Tallahassee; lately rediscovered by A. P. Garber in a hummock. near Manatee, on the muddy border of shallow ponds in water from a few inches to 1½ feet deep, the long leaves floating or spread out on the mud, the inner ones erect; mature in April and May, disappearing in June. Var. *rigida* was found by the same collector on the wet borders of Lake Flirt, not far from Lake Okeechobee, in August, entirely emersed and erect. Mr. A. H. Curtiss seems to have met with a similar form in a muddy swamp on Indian river; none of all of these had any mature microspores. Var. *Chapmani* was discovered by A. W. Chapman near Mariana, West Florida, filling a lakelet of pure limestone water about one foot deep, formed by one of those (in that region so common) subterranean streams, where it comes to the surface before emptying into Chipola river, together with *Nasturtium lacustres;* but the *Isoëtes* has not been seen in it since: its larger macrospores, sometimes quite smooth, distinguish it from the other forms. — This peculiar species, the only one thus far found in Florida, is distributed over the whole State. It cannot be classed with the submerged species, for, though evidently often in deep water, the leaves elongate, seek the surface and float on it. The closed velum and the peculiar sculpture of the macrospores readily distinguish it from its allies.

C. Terrestrial species, maturing when entirely out of water, with abundant stomata and peripheral bast-bundles, thick dissepiments, and small air cavities in the nearly triangular leaves.

* Velum partial or almost wanting.

12. I. MELANOPODA, J. Gay. Polygamous; trunk subglobose deeply bilobed; leaves slender, stiff, erect, bright green, usually black at base (15 to 60 in number, 5 to 10 or rarely even 18 inches long); sporangia

mostly oblong (2 to 4 or even 5 lines long), spotted, with narrow velum, ligula triangular-subulate; macrospores among the smallest in the genus, 0.25 to 0.40 in diam., with depressed tubercles often confluent into worm-like wrinkles, or almost smooth; microspores also smaller than usual, 0.023 to 0.028 or rarely 0.030 mm. long, spinulose.—Durieu in Bullet. l. c.; Gray Man. l. c.

Var. PALLIDA. A larger plant, leaf-bases pale, velum usually much broader, covering ¼ or ⅓ of the sporangium; macrospores only 0.30 to 0.35 mm. thick.

An exclusively western species, in low prairies and fields overflowed with at least one inch of water in spring, or in shallow ponds which dry up in summer, in stiff clayey soil, in company with the ordinary vegetation of such localities, e.g. *Nasturtium sessiliflorum*, *Hypericum mutilum*, *Elatine*, *Penthorum*, *Ludwigia*, *Ammannia*, *Alisma*, *Juncus*, etc., from northern and central Illinois, Ringwood, *G. Vasey;* Athens, Menard Co., *E. Hall;* to Clinton, Iowa, *G. Vasey*, the Indian Territory, in low places in the saline flats near Limestone Gap, *G. D. Butler*, and to the wet pine woods in Hempstead Co. and about Houston, Texas, where the variety occurs, *E. Hall.* Maturing in June or beginning of July.—Mr. Hall was accidentally led to the discovery of this plant on his farm in 1853 by finding its trunks and spores in turning up the soil for brick-making; he has since made many interesting observations about it; he does not find it every year, thus in 1877 there was none at all in localities where before and since it abounded, though the season was wet; another time he found it copiously only in plow furrows in a meadow, and none elsewhere; in wet seasons, when the water is deeper than usual about the plants, the leaves become longer, more flaccid, and even decumbent, and the spores mature later or not at all. In ordinary seasons the leaves disappear entirely in July and nothing but the trunks remain, and about them the numerous spores, both of which are eagerly sought after by mice and other animals. The spores germinate whenever sufficient rain falls in the later summer months, and perfect meadows of young plantlets can be observed in wet autumns. Sometimes the plants are seen as fresh in September as in May, and already 4 to 6 inches high, and in 1865 they were so much favored by the season that a second crop was gathered in November with perfectly mature spores; but it is scarcely probable that these could have been seedlings of the preceding summer, though Mr. Hall is inclined to think so.

The polygamous character of this species has been alluded to on page 363. I will here only add, that a number of monœcious specimens show a preponderance of one or the other sex, and that in a few I have found leaves, which bear male or female sporangia, irregularly mixed.

The dissepiments of the leaves consist of 6 to 9 layers of cells, the lower median being the thickest. Besides the normally 4 peripheral bast-bundles we find here often several smaller accessory ones, which increase the rigidity of the leaves. In no species have I seen the macrospores so variable in size in the same sporangium; large and small ones are indiscriminately mixed; and they are also remarkably variable in their sculpture, showing distinct or confluent vermiculate tubercles, or a nearly smooth surface; the dividing ridges or commissures are very prominent and smooth. The leaf-bases of the typical form of this species are black and shining, and justify the name given by that zealous botanist, Jacques Gay, who in his 75th year was still anxious and able to climb the high mountains in the centre of France, to study in their lakes the two European species which had just then become prominent through the labors of his friend Durieu de Maisonneuve, and who left us such a vivid description of his hardships, excitements and pleasures on that trip (Bull. S. B. F. vols. 8 & 9); death prevented him from publishing it, but his name remains connected with it. Now and then a paler specimen is seen, and the Texan form is always pale, and distinguished also by its broader velum.

13. I. Butleri, Engelm. Diœcious, smaller than the last, with a subglobose trunk and thinner and more rigid bright green leaves, 8 to 12 in number and 3 to 7 inches long; sporangium usually oblong, spotted, without any or with a very narrow velum; ligula subulate from a triangular base; macrospores larger than in last, 0.50 to 0.63 mm. in diameter, similarly marked with knobs or warts, distinct or sometimes confluent; microspores 0.028 to 0.034 mm. long, dark brown, papillose. — Bot. Gazette, 1878, p. 1.

Var. IMMACULATA. Larger, leaves sometimes as many as 60, 6 to 9 inches long; sporangium without spots; macrospores rather smaller, 0.40 to 0.56 mm. in diam.; microspores 0.029 to 0.031 mm. long, spinulose.

In the saline flats (called alkali flats, but impregnated with sulphates) of the Indian Territory, near Limestone Gap, between Arkansas and Red rivers, associated with the few coarse plants which can live in those localities overflowed in winter and spring, and baked hard in summer and autumn, such as *Iva angustifolia*, *Ambrosia psilostachya*, *Arenaria Pitcheri*, and with *Isoëtes melanopoda*, but in rather drier localities than this; maturing in May and June, *G. D. Butler*. The variety near Nashville, Tenn., in cedar barrens, in damp places on the limestone flats, with *Leavenworthia*, *Talinum*, *Sedum pulchellum*, *Schœnolirion*, several *Junci*, etc., *A. Gattinger*.—This species, also peculiar to the Mississippi Valley, is quite unique in this genus by its dioicity, though its nearest ally, the last mentioned one, approaches it. From this it is readily distinguished by the absence of the velum, by the deep brown color of the microspores and the larger size of the macrospores; in these last I notice the peculiarity that the ridges themselves which separate the faces of the spores are also more or less tuberculated, while in other species they are quite smooth.

* * Velum complete.

14. I. Nuttallii, A. Braun in Herb. Similar to the last two species, with an almost globose slightly grooved trunk and 20 to 60 slender bright green leaves, 3 to 9 inches long, with only 3 peripheral bast-bundles; spo-

rangium oblong or oval, entirely covered by the velum; macrospores very variable in size, between 0.25 and 0.50 mm. thick, densely covered with minute but prominent rounded warts, or, rarely, almost smooth; microspores 0.025 to 0.028 mm. long, papillose, brown. — Engelm. in Am. Nat. 8, p. 215; *I. opaca*, Nutt. in Hb. Ac. Phil.

On damp prairie flats or springy declivities in the valley of the Columbia river, *Nuttall;* abundant about Silverton in the Wallamette valley, *E. Hall*, No. 693; at Milwaukee, Oregon, *J. Howell* (with almost smooth macrospores); Klickitat Co., Washington Terr., on Kamass Prairie and at the base of Mt. Adams, 2,100 feet alt., *W. N. Suksdorf;* eastward on Kamass Prairie of the Cœur d'Aleines in Western Idaho, *Ch. A. Geyer*.— The closed velum and the much smaller warts of the macrospores distinguish this readily from the two other terrestrial speeies; it is the only species on which I observe constantly only 3 peripheral bast-bundles, one on each of the three edges, the upper middle one being absent. The median dissepiment of the leaves consists of 8 or 9 and the transverse one of 6 to 7 layers of cells.

II. **Trunk trilobed,** bast-bundles and numerous stomata in the quadrangular leaves; velum partial.

15. I. CUBANA, Engelm. One of the larger species; leaves 30 to 40, 15 inches long, fresh green, with 6 bast-bundles; sporangia oblong, unspotted; velum very narrow; macrospores 0.30 to 0.40 mm. thick, marked with coarse round depressed, never confluent tubercles; microspores 0.024 to 0.027 mm. long, papillose, pale.—Sauvalle Fl. Cub., p. 203, name only.

On the bottom of rivulets in the pine woods of Eastern Cuba, *Chas. Wright*, probably floating. — This is the only American species north of the Equator with a trilobed trunk; it compares most closely with the East Indian *I. Coromandelina* according to A. Braun's observation. The roots form 3 distinct bundles from the 3 grooves; the bast-bundles are found at the four intersections of the dissepiments with the outer walls and at the two upper edges of the leaf.

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI BOTANICAL GARDEN

TABULATED CHARACTERS OF THE NORTH AMERICAN ISOËTES.

	Vegetation.	Trunk lobes.	LEAVES.		Stomata.	Bast-bundles.	Velum.	Sporangium	MACROSPORES.		MICROSPORES.		NATIVE COUNTRY.
			Number.	Length inches.					Diameter, millimeters.	Surface.	Length, millimet.	Surface.	
1. *I. lacustris*	subm.	2	10—25	2— 6	"	0	*n.*	*w.*	0.60—0.80	Cristate................	0.035—46	Smooth ...	North'n N.York to Lake Sup'r
var. *paupercula*	"	2	10—18	2— 4	"	0	*b.*	*w.*	0.62—0.66	"	0.026—36	Nearly do.	Rocky Mountains & California
2. *I. pygmæa*	"	2	5—10	½— 1	0	0	*n.*	*w.*	0.36—0.50	Minutely tuberculated	0.024—29	" "	Californian Mountains.
3. *I. Tuckermani* .	"	2	10—30	2— 3	0	0	*b.*	*sp.*	0.44—0.56	Cristate above, reticulate below	0.026—32	Smoothish	New England.
4. *I. echinospora*													
var. *Braunii*...	"	2	15- 30	3— 6	few	0	*b.*	*sp.*	0.40—0.50	Spinulose	0.026—30	Smooth . {	Pennsylvania northward and northwestward and to Utah.
var. *robusta* ...	"	2	25—70	5— 8	many	0	*b.*	*sp.*	0.35—0.55	With longer slenderer spines..	0.026—31	Smooth ...	New England.
var. *Boottii*....	"	2	12—30	4— 5	few	0	*bb.*	*sp.*	0.40—0.50	" " " ..	0.026—30	Smoothish	"
var. *muricata*..	"	2	15—30	6—12	"	0	*bb.*	*w.*	0.44 0.58	With shorter confluent spines....	0.028—32	"	"
5. *I. Bolanderi* ...	"	2	5—20	2— 4½	"	0	*b.*	*w.*	0.30—0.45	Sparsely and minutely tuberculated........	0.026—31	Papillose .	Calif., Oreg., Rocky Mount'ns.
6. *I. saccharata* ..	amph.	2	10—20	2— 3	many	0	*n.*	*sp.*	0.40—0.47	Minutely tuberculated	0.024—25	"	Maryland.
7. *I. riparia*......	"	2	15—30	4— 8	"	0	*b.*	*sp.*	0.44—0.65	Cristate	0.028—34	"	Pennsylvania to NewEngland.
8. *I. melanospora*.	"	2	5—10	2 – 2½	"	0	*c.*	*w.*	0.35—0.45	Minutely tuberculate	0.027—30	Smoothish	Georgia.
9. *I. Engelmanni*..	"	2	25—100	9—20	"	4	*n.*	*w.*	0.40 - 0.52	Reticulated	0.024—28	"	Delaware to N.Eng.&Missouri.
var. *gracilis* ...	"	2	8— 12	9 - 12	"	4	*n.*	*w.*	0.38—0.48	"	0.024—28	"	Pennsylvania to New England.
var. *valida*	"	2	50—200	18—25	"	4	*b.*	*w.*	0.32—0.48	"	0.024—27	Spinulose.	Pennsylvania.
var. *Georgiana*	"	2	15	10—12	"	4	*n.*	*w.*	0.48—0.56	"	0.028—31	Smooth ...	Georgia.
10. *I. Howellii*.....	"	2	10—25	5— 8	few	4	*b.*	*w.*	0.43—0.48	Coarsely tuberculated.	....	....	Oregon.
11. *I. flaccida*......	subm.?	2	10—35	15 - 24	many	4	*c.*	*w.*	0.30—0.42	Coarsely tuberculated, tub. often confluent	....	....	Florida.
var. *rigida*.....	amph.	2	10—15	5— 6	"	4	*c.*	*w.*	0.30—0.38	" " "	....	....	"
var. *Chapmani*.	"	2	30	18	"	4	*c.*	*w.*	0.41—0.55	" often smooth above	0.027—30	Papillose .	"
12. *I. melanopoda* .	terr.	2	15—60	5—16	"	4+	*n.*	*sp.*	0.25—0.40	" " " " {	0.023—30	Spinulose.	Illinois to Indian Territory.
var. *pallida*....	"	2	10—15	8- 15	"	4	*b.*	*sp.*			....	....	Texas.
13. *I. Butleri*	"	2	8—12	3— 7	"	4	*nn.*	*sp.*	0.50 0.63	Minutely tuberculated	0.025—31	Papillose .	Indian Territory.
var. *immaculata*	"	2	20—60	6— 9	"	4	*nn.*	*w.*	0.40 - 0.56	do. or nearly smooth	0.029—31	Spinulose.	Tennessee.
14. *I. Nuttallii*.....	"	2	15—60	3— 9	"	3	*c.*	*w.*	0.32—0.52	Minutely tuberculated	0.025—28	Papillose .	Western Idaho to Oregon.
15. *I. Cubana*......	amph.?	3	30—40	15	"	6	*n.*	*w.*	0.30—0.40	Coarsely tuberculated.	0.024—27	"	Cuba.

EXPLANATIONS.

VEGETATION — submerged, amphibious, or terrestrial.
VELUM — *n* means narrow; *nn*, very narrow: *b*, broad; *bb*, very broad; *c*, closed.
SPORANGIUM — *w* means white or unspotted; *sp*, spotted with dark sclerenchym-cells.

MISSOURI BOTANICAL GARDEN
GEORGE ENGELMANN PAPERS

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI
BOTANICAL
GARDEN

0 1 2 3 4 5 6 7 8 9 10
cm copyright reserved
MISSOURI
BOTANICAL
GARDEN